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AN EXPERIMENTAL STUDY OF CERTAIN INITIAL PHASES OF THE PROCESS OF ABSTRACTION[1]

By HORACE BIDWELL ENGLISH

INTRODUCTION

In all previous investigations of the process of abstraction, the subjects were instructed, generally most explicitly, what to abstract and what to abstract from. Thus Külpe (10) in the earliest study instructed them to attend to one quality only, such as the color, of a complex object; while Fisher (7) in the latest and most complete investigation instructed her subjects to define certain groups—a task which to civilized adults could mean only to abstract the common element. Such procedure obviously leaves uninvestigated the impulse which leads one, without such instructions, to react to a situation by making an abstraction. Is it true, as Max Müller says and as Wundt implies, that abstraction springs from our weakness rather than our strength; that we abstract because we are unable to have regard to the complex fullness of experience? Or must we in some form revive Hume's "distinction of reason?" This is the problem we set ourselves to study.

METHODS

The essence of the experimental method adopted was to put adult subjects in the presence of certain carefully-prepared situations and to require of them a report of their reactions. These were then studied for indications of the first steps toward abstraction. No attempt was made to separate two factors in-

[1] A condensation of a dissertation accepted by the Faculty of the Graduate School of Yale University in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

evitably present in any such situations: present experience and funded, past experience. Under the conditions of our experiments, at least, the latter seems always more influential; but the two factors are so closely knit together that separation would be impossible. That particular assimilative union of present with past experience which leads the subject to make an abstraction we shall call the "cue" to abstraction.

In technique, the experiment owes its original inspiration to the experiments of Aveling (3), but important changes, growing more marked as the work advanced, were made. The following acted as subjects: Professors R. P. Angier and E. H. Cameron, Drs. A. E. Avey, R. M. Elliot, J. H. Philp, A. H. Sutherland, and Miss Helen Whitney, Miss Olive M. Jones, Messrs. Mark McChesney, C. A. Murchison, and Gardner Murphy. Messrs. McChesney and Murphy were seniors completing a major in psychology, the others were graduate students and instructors in the department of philosophy and education. Except Miss Jones and Messrs. Murchison and Philp, all had had considerable practice in introspection. To all of these I take this opportunity of expressing, most inadequately, my thanks. To Professor Angier, for advice at all times and help in preparing the results for publication, especial thanks are due.

The experiments divide themselves into four groups: *a*, *b*, *c*, *d*.

Group *a*

It was in this group that Aveling's technique was most closely followed. "The material employed consisted of ten sets of small pictures and ten nonsense-syllables of two syllables each. There were five pictures in each set. All in each set were sufficiently alike to be designated by some common name; yet each possessed sufficiently notable characteristics as well, by which it could be singled out from the others." Thus Aveling (3, 78 f.).

The first seven sets (the only ones used in the first ten sittings) were designed to reproduce Aveling's material as closely as possible. The pictures were of the following classes of objects: Set 1, *Bekis:* curvilinear geometrical figures; Set 2, *Dojaf:* musical instruments; Set 3, *Hexur:* soldiers; Set 4, *Fefiv:* flowers; Set 5, *Wocag;* straight-lined geometrical figures; Set 6, *Tugic:* receptacles for liquids; Set 7, *Vupaw:* fruits.

The common element in each set is thus some familiar class concept. On the basis of our experience with these in the first ten sittings a marked change was made in the three new sets to be introduced for the next ten. The common element was in each set a rather complex, geometrical pattern. This was identical in each member of the set and differed from the other two patterns by certain fairly obvious characteristics (see Fig. I). These patterns were laid upon various regularly or irregularly shaped colored figures. It is clear that corresponding to each nonsense-word of the first seven sets is an abstract universal, to each nonsense-word of the last three sets, an abstract or abstracted particular.

Each picture was shown for ten seconds, then after one minute (during which the subject read or conversed with the experimenter on indifferent subjects) again for five seconds. After two minutes, another picture was shown. A very simple tachistoscope was used. The instructions, which were read verbatim to the subjects each session until perfect familiarity rendered this unnecessary, were as follows:

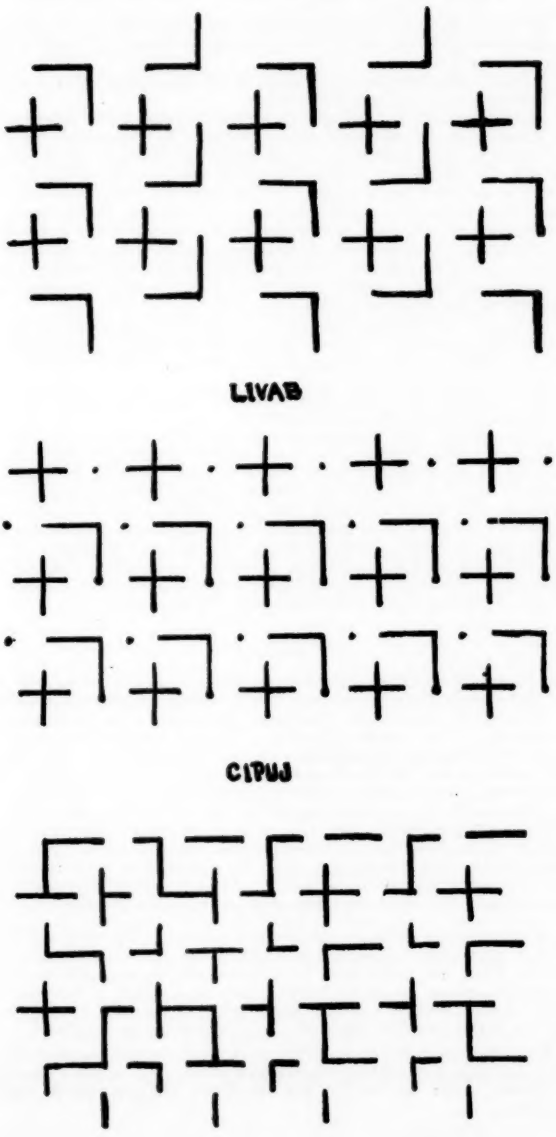

FIGURE I

"I shall show you a picture and a nonsense-word for a short time. Repeat the word aloud, once, while you regard attentively both word and picture above it."

Subjects were warned not to think of the experiment during the interval between pictures or between sittings.

For the first ten sittings, one each from the first seven sets of pictures was shown with its associated nonsense-word. In the second ten sittings from seven to nine pictures were shown. This included always one each from the last three sets of pictures and a selection from the seven sets learned in the first ten sittings. Certain pictures were shown more frequently than others. In some cases also, a picture was shown two or three times before a second member of the series was shown. This was done in an effort to bring out the effect of repetition and of dissociation by varying concomitants. Five minutes' rest was allowed after the presentation period. The subject was then placed in front of a simple exposure apparatus and the following instructions were read to him:

"You will now be shown the nonsense-words you saw with the pictures. As soon as the meaning of the word is apparent to you, react by pressing this key. You will be asked to report in what guise or form the meaning comes to you."[2]

The subjects demanded a definition of "meaning" and were told to give the word its everyday significance.

From time to time nonsense-words not in the series at all were introduced as "Vexierversuche" and in the second ten sittings nonsense-words belonging to pictures previously "learned" but not seen during the presentation period of that sitting were occasionally presented for reaction and report. It should be noted that one subject (An.) was familiar in a general way with the arrangement of the experiments; but full account of this fact will be taken in evaluating and classifying his protocols. Subjects wrote their own protocols and were questioned upon them very sparingly. Sittings were held three times a week and lasted about fifty minutes. The experiments of this group were held in the spring of 1915.

Group *b*

In place of the pictures shown in Group *a* musical selections were played on a phonograph, the nonsense-word being visually presented simultaneously. Allowing for the change of material, the same instructions were given as in Group *a*. The common element in each of the first four sets was the manner of producing the selection. In the first set, all the five selections were baritone solos; in the second set, duets by male and female voices; in the third, mixed vocal quartets; in the fourth, band selections. The fifth set introduced a cross-classification. All of the foregoing were small ten-cent records requiring less than half the time to play taken by the standard large-sized records.[3] The music was not only "raggy" but, except for the band selections, atrociously executed by both "artists" and record manufacturer. Set five consisted of two standard large-sized records, well executed. The music also was superior, even the popular "Tipperary"

[2] As the buzzing of the Ewald chronoscope used in timing these reactions disturbed and hurried some of the subjects, the stop-watch was later substituted. Even this might have been eliminated, since no use was made of the reaction-times. It is advisable, however, to have the subject react in some decided way in order to put a period to his train of thought; and when this is the case, the stop-watch may be harmlessly employed.

[3] Our subjects found great difficulty in remembering the selections well enough to form any constant associations at all; and, as the subjects were not allowed to see the records, the visual size of these records could not help them.

being better than the selections on the ten-cent records. Set five, therefore, was differentiated from the other sets by superior aesthetic qualities and by much greater length.

One subject could give but ten, the other but eighteen sittings to this part of the experiment, in which time no real abstractions were made. Certain preliminary stages of abstraction were, however, brought out. One subject (Av.) had read Aveling's book and supposed that we, like him, were interested in "imageless thought." His special knowledge of similar experiments probably played some part, but did not keep his protocols from presenting many points of interest.

Group *c*

Our experience in the experiments of Group *a* indicated two things. One was that the classification scheme should be more complex and more difficult. The second was that "nonsense-pictures" should be used, *i. e.*, pictures to which an English class-name cannot readily be given. It is impossible by this means wholly to avoid the influence of funded associations, as most investigators have found. It does not follow that there are not very great advantages in the use of nonsense-pictures. In nearly every case, it is true that the visual presentation will be apperceived as "like something" else and that the name of this "something else" will be used as a verbal tag to aid memory. But such a verbal tag will not suggest to the subject the basis of the grouping. An example will make the difference clear. Immediately upon seeing the first picture, *Hexur*, the subjects without exception thought "soldiers". Thus the basis of our grouping was given, and the subject's task was one of differentiation. This is an interesting process but not the one in which we are primarily interested. Upon seeing a certain *Jekog*, the subjects thought "dumbbell". This verbal tagging helped them to reinstate the whole picture, but it gave no clue to the one element referred to by *Jekog*, which was a certain pattern.

It proved to be by no means easy to construct a series of presentations that would answer our purpose. In the end it was decided to adopt the following scheme. A one-to-one relation between certain outlines (see Fig. II) and certain syllables, and between certain other syllables and certain patterns (see Fig. III), was determined upon. Each succeeding day a given outline would be shown, cut from a different pattern-paper, and every sixth day it would appear twice, *i. e.*, cut from two patterns. Similarly and as corollary, each pattern appeared with a different outline each day and with two every sixth day.[4] But whenever any pattern or any outline was shown, its syllable stood beneath it. Thus beneath each of these composite pictures was an outline-syllable and a pattern-syllable. Other features of the pictures such as color and orientation varied irregularly. The subject saw six pictures each day for two five-second intervals. Between exposures the subject read from a volume of letters. After going through the whole list twice in this fashion, the syllables were presented to the subject one by one and he was required to report his reaction to them.

The following instructions were read by the subject at every sitting until their content was perfectly familiar:

"I shall show for a brief exposure a picture with two nonsense-syllables under it. Regard the whole picture attentively and pronounce the nonsense-syllables aloud once."

"You will be shown one of the syllables presented in the exposition period just finished. When you feel that you know to what it refers, press down this key sharply so that I can hear it click. After a moment's pause

[4]The two presentations of the repeated pattern (or outline) were some distance apart in the series.

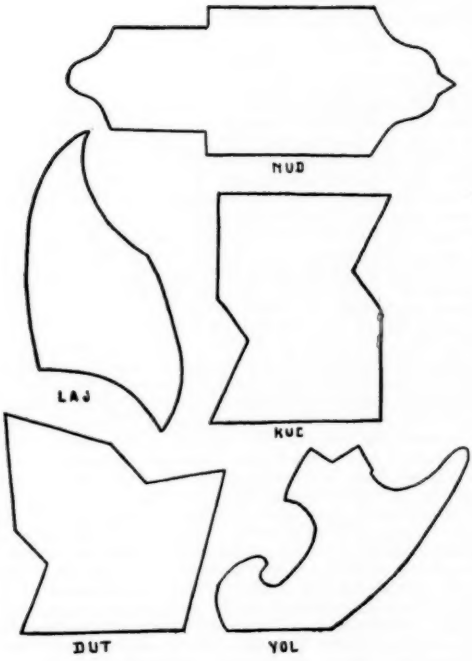

FIGURE II

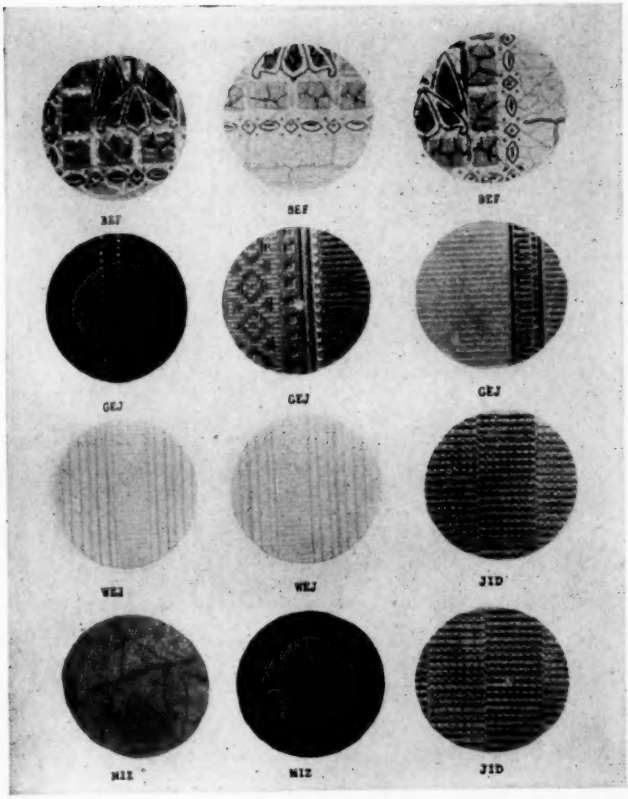

FIGURE III

in order to allow any further mental process to develop which may be relevant to the experience just finished, write an introspection of the experience."

The supplements to these instructions and the influence they had on the subjects will be considered later.

Beginning with the subject's third or fourth sitting, instead of writing his protocol, he was asked to dictate it to the dictaphone.[5]

One subject (S.) was completely inhibited when he tried to dictate an introspection to a machine. He simply could not utter a word and was obliged to write his report. Another subject (J.) was disturbed very considerably; after several day's trial it was decided that she should also be allowed to continue writing. The remaining subjects soon accustomed themselves to the procedure and very much preferred it. Where an experimenter does not know shorthand—as few do— the use of such a machine has very many advantages.

During the first seven sittings the pattern syllable was invariably given first and the orientation of the figures on the card was constant. In the seventh sitting and irregularly thereafter the two classes of syllables were in some cases reversed and the orientation of the two outlines *Yol* and *Dut* was radically altered. The intention was to dissociate these really variable elements from the two essential ones of pattern and outline. The actual effect was at first to draw attention to these variables and to set the subjects speculating on them. Finding no rhyme or reason in the changes, they accepted them as a fact and paid no further special attention to them. Three sittings a week were given during the fall semester of 1915. An. was too familiar with the problem to be wholly naive, while W. was undoubtedly somewhat influenced by her experience as subject in Group *a*.

Group *d*

This was a very short, control series in which the general plan of Group *c* was followed with auditory presentations substituted for visual. One set of syllables referred to the method of producing the sounds, another set referred to the tonal phrases produced. Three instruments were used: a zither (*Vop*), a small tubaphone (*Rev*), and a series of small organ pipes, (*Wug*). The phrases in terms of the key note were: Do-Do-Fa-Sol (*Kev*), Do-La-Mi-Fa (*Faf*), Ti-Sol-La-Sol (*Tuj*). Subjects were not allowed to see the instruments used. The instructions followed the lines of those in *c* slightly amplified, but two subjects (El.) and (Mp.) were told the purpose of the experiment. Another (Mn.) had been subject in *c*, but had not reached an abstraction, and was in the dark as to the purpose of the experiment.

It will be observed that the task set in Groups *c* and *d* is the same as in the latter part of *a*, that, namely, of abstracting from a series of situations a particular (as contrasted with a universal) common to them all.

In quoting from protocols, the initial of the subject is given first. The small letter indicates the experimental group, the Roman numeral indicates the number of the sitting within the group. The nonsense-word presented for reaction is next given, followed, in parentheses in the case of protocols from Groups *c* and *d*, by the syllables presented with it in the "presentation period". Thus P., *c* XII *Yol* (*Bef*) would mean that the quotation was taken from the protocol of Dr. Philp in sitting XII of Group *c*, dictated after reacting to *Yol*, one picture in that sitting having been combined from *Yol* and *Bef* (see Figs. II and III).

It should be noticed that our subjects were in no way required to give an analytic introspection of the process of ab-

[5] This was very kindly lent us by the Columbia Graphophone Co. We take this opportunity of acknowledging the courtesy.

straction. What they were required to do was to report the train of associations aroused by certain words. The nature of these associations, however, throws considerable light upon the progress and nature of the abstractive process. The task imposed did not prove a difficult one, even for inexperienced introspectors, requiring chiefly a fair psychological vocabulary. Nevertheless, we have nowhere based a conclusion upon the evidence of those subjects not accustomed to introspection, unless it is confirmed by one at least of the others. On the other hand, though we did not require it, a certain amount of analytic introspection was offered and is used as evidence.

Since our purpose is rather to discover and illustrate processes which are to be found in abstraction, than to determine those which are not, it is necessary to quote only so much from a given protocol as will clearly exemplify the point under discussion. Nevertheless, a great many protocols are quoted in full, especially where an effort is being made to characterize a certain phase or process as a whole. These reports are marked with an asterisk.

The Preliminary Phases as Analysis and Conception

We find that the process of abstraction begins in one of two ways: either the situation-complex is *assimilated as a whole* to some familiar conceptual category; or, where this is impossible, its unity is broken up and the situation is *analyzed* into such of its simpler components as will permit of such assimilation. Since a "real" analysis in things psychical has been denied (*e. g.* by Ameseder **2**, 494 f.), it may be well to point out that by analysis we mean more than a distinction of the constituents of an experience. The constituent parts of an experience and the experience itself must be different after analysis. Now, as James says (**9**, 245), "the law is that all things fuse that can fuse." When, therefore, an originally unitary presentation not only is broken up into simpler components, but *remains* broken up, something must intervene to prevent an immediate recombination. For there would obviously be no inherent obstacle in the way of a fusion of elements which had once been fused.

And it is perfectly clear what this divisive influence is; it is the assimilation of the components to distinct mental categories. In analysis, at any rate as we shall use the term, the various features of the complex situation are thought of as relatively independent elements having validity outside the presented complex, as numerically distinct objects of thought. In James' terminology, they are conceived. If one cares to state it so, therefore, one may say that the first phase of the process of abstraction is the assimilation of the presentation either as a whole or in parts to preformed conceptual categories. Such a

statement emphasizes the essential likeness of the two types we have distinguished; it is more to our present purpose to bring out the differences between the first phase as analysis and as assimilation.

As was implied above, the chief determinant as to whether analysis or assimilation shall take place lies in the nature of the presented situation-complex. If this is some familiar object, assimilation promptly takes place. If, on the other hand, the situation as a whole is unfamiliar or novel, it is broken up, in a manner to be described, into such fragments as *are* familiar. Hence the presentations of the first ten sittings in Group *a* were nearly always assimilated, the new ones introduced in the second ten were more often analyzed. So, too, in Group *c*, most of the presentations were, from the first, subjected to analysis, but a few that looked most like familiar objects were assimilated.

For example, compare the protocols of subject W., taken after the first presentations of *Hexur* and *Jekog*.

"This gave me a visual verbal image of hussar. Then I saw immediately the three soldiers in the blue and buff uniforms. The image 'hussar' and the visual image of the picture seemed to be almost simultaneous."

"First I knew I had seen that. And I also knew I had only seen it once, and then I started to think about figures filled in with geometrical signs (visual imagery). I then got a visual image of the white hexagon filled in with 'pluses' and 'angles' done in red ink."

It should be understood that many of the protocols present odd intermediate forms or a mixture of both types. Analysis and assimilation are by no means exclusive. The essential difference between them is, of course, that, in the one case, the situation is treated piecemeal; in the other, as a whole. But it not infrequently happens that, an analysis having been performed, the subject discovers among the components one which somehow serves as a representative of the whole, and thus is led to the conceptual attitude.[6]

The Cues to Analysis

Taking up analysis first, our problem may be defined as the finding of the cues of analysis. Since our experiments were carried on with adult subjects, it may seem that we have in the analogy to past experience an easy solution. It is, indeed, too easy. Two forms of analogy may be meant. In one, the subject decides to analyze because he has previously found it profitable to analyze unfamiliar situations. Yet how he is to divide the

[6] "Attitude" is used throughout this paper somewhat loosely in accord with its untechnical but well-established significance, without regard to the question whether the "attitudes" correspond to the "Bewusstseinslagen" of Marbe (11) and Orth (13), or of the "fundamental personal attitudes of the self" of Calkins (6).

complex, to what previous situation the presentation is analogous, is still undetermined. We give some attention to these processes below under the heading of "Deliberate Analysis." Another form of analogy consists of a more detailed likening of the present to the past. Such analogy depends upon analysis far more truly than analysis depends upon it. It is only when we become conscious of the presence in the present situation of the same cues or factors which led to the analysis of the past situation, that past and present are thought of as analogous (cf. Bühler, **5**, 338, where such a "Regelbewusstsein" is said to be the basis of analogical thought.)

A second important point concerns itself with language. Although logicians and philologists had long ago decided that language is essentially abstract and analytical, no serious effort has been made by previous experimenters to determine the effect of the use of language upon the analyzing and abstracting consciousness. Yet one finds obvious traces of it at every turn. Thought, as Plato (**4**, 189 E) says, is little more than a conversation with oneself—at least, for most of us. And the necessity in these experiments of making a report, in words, forced even those not so much inclined to verbal thought to express in analytic terms what may have been a unitary experience. In no single instance in all of the protocols studied (some 2,000 in all) was this factor entirely absent. But it works generally in close union with some other factor, so that the analyzing function of speech is dealt with chiefly under other headings.

1. *Attentional Cues to Analysis.*—During even a five-second exposure attention does not remain upon any one feature of a presentation, nor is it of a constant level. A temporal or, what would seem to be equally effective, a clearness distinction of the components of the complex is thus effected. Exactly what it is that leads these temporally distinct objects to be conceived of as numerically distinct is by no means easy to say, though we shall take up below some of the cues to conceptualization. We may usefully insist at this point, however, upon the part played by language. Once separated in any fashion, the various features of the complex are almost invariably *named*. Now it is theoretically possible to use names and not think about the corresponding concept. Yet the connection between a name and the concept it signifies is so intimate, so frequently exercised, that the name very seldom occurs without at least incipient general notions attending it. Examples of this cue to analysis were very frequent and would undoubtedly have been more frequent had we taken introspections on the presentation period.

W., *a* VIII, *Hexur.* "I noted that their faces were different and I also noticed the direction in which they held guns, namely, from upper right to lower left."

J., *c* XVI, *Yol* (*Bef, Jid*). "I noticed in presentation period particularly its position with head lowered and with a red spot on its nose, as well as in central part of figure."

S., *c* XXI, *Nud* (*Wej*). "Visual image of [draws figure] with vertical lines across surface. There was a hesitation about reacting to this for a moment, but almost immediately the vertical lines leaped into greater prominence and the reaction proceeded."

Mn., *c* XIV, *Gej* (*Laj, Yol*). "I had two visual images upon the appearance of this syllable. The first one was the candle-flame picture, gray color, with the syllables *Gej, Laj* occurring beneath it. Then immediately it disappeared and I had the revolver picture, deep red color, the syllables *Gej, Yol* occurring beneath it. Then I reacted. I did not react after the first visual image because I felt certain that another visual image was coming, so I waited for it. In the case of the visual image of the candle flame it was the form, the outline, that was the most distinct and clear. I did not pay so much attention to any of the contents of the image. The form of the candle-flame picture was very bright, metallic, glittering around the edge, but in the case of the revolver picture I paid as much attention to the contents of the picture as I did to the form, I suppose because of the deep red color."

2. *Memory Cues to Analysis.*—The exposure of the syllable in the reaction period tends by a law of preferential revival to recall all of the situation with which the syllable was that day associated. But it only *tends* to do so. Some features are remembered quite badly, much is altogether forgotten. This is certainly due in very large part to differences in attention to these features during the presentation. Yet not altogether. Rather must we suppose that the same apperceptive interests (including the innate) which condition attention also favor recall.

In general, this distinction of elements becomes a conscious analysis in much the same way that the attentive distinction does. For several reasons, however, the transition is less abrupt. In the first place, the separation is much more complete. As has been above remarked and as will be illustrated below, some of the elements are entirely forgotten; the separation is here very nearly absolute.

A second and most important cause is the greater part played by speech. For example, after he had described rather minutely his visual images, S. wrote: "All of this was unitary; there was no temporal order in the visual process" (*c* VII). He is required, however, to characterize his visual image. Such characterization involves temporal separation of the various features; and *it involves giving to them some sort of name* in order that the experimenter may recognize them—by which means, however, the subject has for himself marked off the element from the rest of the world. This process may or may not occur where the selective function is attention; but, under the conditions of our experiment, this naming and describing of the features thus differentially preserved by memory is obligatory. The subject must tell *what* is vague, *what* clear. We might very

well put all such cases under the heading of "Analysis by Characterization." We prefer to keep these cases under the present heading on the grounds that the influence of memory is always clear, while the influence of the language factor is not always unambiguously indicated as important; and to separate cases otherwise so similar would be obviously artificial. This concrete difficulty in classification will serve, however, to illustrate the difficulty of drawing sharp lines of distinction.

The number of examples classed under this heading is very great, of which we can quote only a few.

An., *a* XIV, *Jekog*. "Then a blotch of yellow visually and then the yellow dumbbell with its inner pattern. Last not distinct; cannot reproduce pattern now."

C., *a* XII, *Livab*. "Auditory-motor verbal 'yellow' followed by a vague image of an irregular yellow figure with curved outline. Since writing, some vague visual imagery of figures composed of red lines."

W., *a* XVII, *Cipuj*. "I got a visual image of mustard-colored circle, but the figures inside were pretty dim."

Av., *b* VII, *Hexur*. "Word familiar, slight period of search; violin recalled, and a part of the melody very clearly."

An., *c* II, *Yol* (*Gej*). "A growingly distinct image of the fancy pistol pointed to the right, red, but with pattern indistinct."

Mc., *c* VII, *Dut* (*Miz*, *Wej*). "Not sure of color, but I have a good outline of the picture."

P., *c* V, *Yol* (*Miz*). "Also associated visually with a bright silvery picture, the general shape of which does not appear."

S., *c* IV, *Jid* (*Yol*). "With them came a visual image of a cream-colored brownish surface of vague outline."

W., *c* I, *Bef* (*Yol*). "It was not very clear; I could not remember the outline, but then red and green figures (square in form) stood out upon the tan background."

A definite sub-class is formed by those cases where the elements are distinguished not so much by inequality of retention and recall as by their time and space relations in memory. Three types occur: the one feature supplants the other; the one feature adds itself to the other and both persist as a composite picture: or the two are simultaneously present as visual images spatially separated. Owing to the independence of features thus appearing, these cases form very useful aids to conscious analysis. Both elements are present to consciousness, separately noted and (at least in the protocol, if not before) named; yet they are present not as perceived or imagined unities, but as distinct facts.

El., *c* IV, 6 *Gej* (*Laj*, *Kuc*). "Vest shaped figure, brown stripes. Followed by an appearance of the same figure with a green, slightly mottled surface, much more uniform."

W., *a* I, *Bekis*. "The word seemed familiar, and then immediately I said to myself 'first', meaning it was first in the series. I then got a visual image of the yellow drawing paper, as I had a decided feeling that the yellow drawing paper was used in the picture. Finally I remembered that I had first seen a circle in connection with this drawing paper. This was a visual image. The whole visual image was then very clear."

An., *c* III, 4 *Miz* (*Dut*). "Then the image of the same leafed pattern, with the tan hue, and immediately on that the form something like a zed."

Mn., X, 9 *Kuc* (*Miz*, *Wej*). "As soon as I had these two images in my mind, I could see them both, because each picture was of the same shape. It was a picture taller than it was wide, with an angle cut out of each side. One of them was brown and the other was gray. Under the brown one occurred the syllables *Miz-Kuc* and under the gray one occurred the syllables *Wej-Kuc*. Both images seemed to be perfectly clear in my mind. They seemed placed side by side with the syllables very distinct under them, both visual images."

How this subject avoided abstraction under these circumstances may well seem mysterious, but will be explained later.

3. *Associative Cues to Analysis.*—If we are reminded of one situation by another, it is in virtue of some feature or features identical in both. Not only in these experiments but also in ordinary life, the association is "immediate" or "unconscious", that is, the subject seldom or never reasons upon the logical implications of comparison just spoken of. Yet the presence in consciousness of a memory-image composed partly of elements found also in the presented object seems to favor the selective apperception of those elements of the presentation. Külpe (**10**) and Grünbaum (**8**) found somewhat similar results. Sometimes, of course, the favored features will be taken as representatives of the whole to which they belong, and in this case we have assimilation. More often the partial analysis begun thus by associative emphasis is continued in some other way. The number of examples of this cue is small in these experiments, but there seems reason to suppose it is to play a larger part under other conditions.

S., *b* III, 6 *Wocag*. "There was at the moment no reference to the music, but immediately after the reaction there came the meaning 'first exposure; music fairly like Old Black Joe'." The subject can only get hold of that part of the music-presentation which is like a familiar song. This phrase, however, the subject recognizes as merely one element in the song. He remains with what is felt to be an incomplete analysis. Subsequent presentations fail to enable him to complete it, and the subject's attitude gradually changes to the conceptualizing. The only meaningful phrase comes to symbolize the whole piece, and the subject refers to it as "that Old Black Joe plagiarism."

P., *c* XII, 6. "The syllable *Wej* is associated immediately with *Wej*, *Dut*, and almost simultaneously with the two pictures with the same-colored paper, one of them tall and thin and the other more bulky, smaller. In the images there seems quite distinct a tracing of the lines, especially the reddish lines. All lines are horizontal on the pictures, and *Wej* seemed to stand equally beneath either picture. No other verbal association came with *Wej*, *Dut*, which seems to stand underneath the first, the tall narrow picture, but as far as seeing in any sense the syllable *Wej*, it seems to be under both or under them as a single syllable. The pictures seem side by side and some way *Wej* in just one form stands under them."

4. *Analysis by Characterization.*—It is difficult to exaggerate the importance of our speech-habits in the process of analysis and abstraction. We have seen above that it preserves and con-

solidates the distinction effected by the selective agencies of attention and memory. It has, however, an independent analytic function. Our subjects were required to characterize their reactions to certain stimuli, chiefly in words, though often by drawings also. Now, both of these agencies are analytic. A visual image or a feeling or a concept may come to mind as a unitary experience. Anything approaching an adequate characterization requires an extended description by the use of spatially and temporally separated line-drawings or words. These lines, these words, have all been used by the subject in other contexts; and by whatever mechanism (whether subconscious "Bewusstheiten," marginal images, or what not) are present in this context as psychic universals, *i. e.*, as elements in other contexts as well. And it is precisely this process of breaking up a complex into elements having validity outside that complex which we call analysis.

We have spoken as if the necessity of characterization inevitably leads to analysis; and this is not, by our own showing, the case. The alternative is characterization which is incomplete, though adequate for particular purposes. Such characterization is dealt with later and need not detain us here. Whether in real life representation or complete analysis is more common, we cannot say. In these experiments, the comparative novelty of the experience led to more cases of analysis.

Examples, however, are hard to give. For while every quotation in this section and most in the next are couched in a form undeniably analytic, it is difficult to get examples to show that the analysis is *due* to the tools of characterization. Perhaps the clearest example is the following from subject S.:

S., *c* VII, 8 *Bef* (*Kuc*). "Verbal kinaesthetic processes followed promptly by visual image of creamy background with three green-red smaller figures. All of this was unitary; there was no temporal order in the visual process."

C., *a* XIX, 1 *Jekoq*. "Pronounced word to self. Period of search. Auditory-motor-verbal 'right angle' plus 'attitude'. I shall now proceed to analyze what this latter part means. It is 'plus' (auditory-motor verbal terms) and another 'attitude' which means this figure 1. I can't say whether this last comes as a visual image or not, but probably it does."

J., *c* II, 6 *Nud* (*Miz*). "The picture as seen in the experiment was visualized. The upper and lower parts resembled small cupolas on buildings."

J., *c* IV, 5 *Laj* (*Wej*). "It called to mind a picture with narrow green and brown stripes." After writing this, the subject complained that the picture was perfectly clear but that she found it difficult either to describe or to draw. In attempting both, she was forced to analyze the complex.

5. *Deliberate Analysis.*—This is not to be thought of as a sort of catch-all for protocols which cannot otherwise be classed. There are many, many such, but they have been quietly put aside; there is no pretence in this study of either finality or completeness, hence no need to force classification beyond the

point necessary to render the data intelligible. The protocols here dealt with form a very definite class; though, as with all the classes, the division lines are sharper than any individual case warrants. The analysis in all these cases is proposed by the subject to himself as a thing to be desired, and is deliberately and reflectively made. The questions arise: what suggests to the subject that he make an analysis, and how does he know where to put the lines of cleavage?

The nature of the perceived situation largely determines the latter, and our experiments do not offer a sufficient variety of situations to enable us to discover any uniformities. In some cases, of course, the lines of cleavage are already partly marked out by the selective processes of sensation, attention, or memory, as above outlined.

To the former question, the protocols return a better, though still incomplete answer. There seems to be an infinite variety of things which suggest an analysis. One is simply habit. Some people, especially those accustomed to scientific or philosophical thought, attempt an analysis of practically every novel situation in which they find themselves. This appears, however, less an independent suggestion than an aid to the others.

Another very important suggestion comes from memory habits. Quite independently of psychological proof of the fact, many persons have discovered that they can remember concepts better than images, the elements of a situation better than the total impression. Take, for example, the following general report by subject S. offered at sitting XIV (Group *c*):

"There came to me at about the second or third member of the second exposure the query: 'I wonder if there is not an easier method of impression—by grouping, say.' I then ran my attention back over the members of the series which had been exposed and noted color. This was rejected because no two forms seemed to be the same. Then syllables, some of which I remembered were repeated; but there seemed to be no clue by which to associate them, nothing the same except the syllables; so I gave it up for the time being and concluded without a group."

Another subject, Mn., seems to have given a quite individual twist to this. His procedure was to liken each syllable to some well-known word, then to find in the picture some feature corresponding to that word. Thus, syllable would call up word, word feature, feature entire picture. Needless to say, the task required considerable imagination for its fulfilment. For our present purpose, however, the point to notice is that, in the service of memory, the subject analyzes the presentation.

c III, 5 *Yol* (*Wej*). "Then I immediately remembered that when I saw the syllable a few minutes ago I connected it up with the word 'yawn'. Then I tried to associate the word 'yawn' with the picture which was given, and I remember now that it was the picture of a revolver. I tried to make that picture of a revolver look like 'yawn' during the presentation of the series, but I could not succeed; but I remember very distinctly the attempt. I do not recall the syllable which occurred with *Yol*."

c III, 8 *Wej* (*Yol*). "I tried to find something in the picture with which it occurred that resembled a wedge. I tried to find some visual association that would help me to remember the syllable when it should occur again in the part of the experiment that is now going on, but I can't recall the picture; I can only recall that it was very difficult for me to find anything about it that resembled a wedge. It had too many curves. The syllable is getting mixed up in my mind right now with that picture that resembled a revolver."

c IV, 4 *Kuc* (*Gej*). "I immediately remembered this syllable as one that in the former experiment had occurred with the syllable *Bef*, and the picture somewhat resembled a piece of beef under a microscope. When the series was first begun, at the beginning of this hour, this syllable, *Kuc*, was presented to me in combination with another syllable, *Gej*. They both occurred with a picture which somewhat resembled a letter 'z'. The picture was built up in three sections, dark gray in color. I wondered, at the time, when the picture was first presented to me, why the syllable had been changed. That made me take particular notice of what syllable it had occurred with and the kind of picture it occurred with."

The last of these as a mixed case will serve to introduce us to the next form. The subject is conscious of changes: perhaps he notices the lack of a certain feature where his past experience led him to expect it, perhaps he simply realizes that there has been an alteration. The result is the same, an analytic examination to discover what is changing, what is constant.

P., *c* VI, general: "It has seemed to me that while the shapes of the pictures remain the same, the position of the different shapes changes somewhat and the colors are not always remaining the same for the same shape of pictures, though the same shades of colors seem to be present in the different experiments. The syllables, too, seem to be changing somewhat to make new associations."

A single protocol from subject J. also clearly belongs here.

c X, *Nud* (*Miz*). "The figure within the square made me think of a butterfly, but its red color was inconsistent with that object." Here the subject is struck by a resemblance, but notices also the incongruities. This leads to an analysis to make clear the points of likeness and difference, in this case shape and color respectively. There is small doubt that there are many other suggestions which might lead to deliberate analysis, but these are all that gave evidence of themselves in the protocols.

Analysis would seem, therefore, to be furthered under our experimental conditions by cues depending upon the occurrence of such functions as attention, memory, association, linguistic or allied characterization, and deliberate intention. That the list is complete, even for our experimental conditions, is not contended; but a careful sifting of the protocols fails to bring others to light. Clearly the attention and memory cues belong together as aspects of the selective nature of consciousness. The different features of the presentation have, so to say, different values for consciousness. The position is not clear of the third mentioned, where that element of a presentation which acts as the associative link is subjected to analysis; but on the whole it, too, would seem to be a case of "apperceptive" effectiveness of such a presented feature. Language and allied symbols

are so essentially social that the cues to analysis through "characterization" might even be termed the social cues, even in those cases where verbally-minded subjects characterized—and thus analyzed—without reference to the necessity of making a report. The apparent self-determination of consciousness (which must be accepted as a phenomenological datum) sharply distinguishes the last cues from all the others.

It may not be from the point again to call attention to the somewhat artificial nature of this classification. The necessity to characterize and the determination to analyze can never of themselves lead to analysis since they do not indicate lines of cleavage. On the other hand, the cues of the "selective" group do indeed mark out division lines, but do not suggest that these be followed. In short, analysis is essentially a single, unified process. Yet one must not neglect the fact that in the one case the emphasis in the subjects' protocols was upon the lines of cleavage; in the other, upon the need to follow them. Nothing that has been said above is intended to convey the idea that any of the cues is exclusive of the others. So little is this the case that the chief difficulty has been to disentangle them sufficiently to render classification, and hence intelligibility, possible.

The Cues to Conception

The inveterate tendency to apprehend facts in various relations (which seems to be the fundamental impulse towards analysis) may be satisfied not only by analysis, but also by conception. It will come as a shock to some to find conception put at the beginning instead of the end of a process of abstraction, and the question will at once be raised as to what we mean by the term. We mean that the presented object is perceived *as* something, is thought of *as a case or an example* of something, is assimilated to certain mental categories. By whatever name it be called, this is often a first step to abstraction.

If we bear in mind, as we must always do, that the subjects of this experiment were adults, the statement loses its mystery, even for those who are committed to the view that our concepts are reached by a process of abstraction. Our subjects were able to (and did) use constantly the concepts attained, if you will, by previous abstractions. The object is conceived as a member of a certain class. Now in strict logic, it belongs to a class only by virtue of its possession of certain abstract qualities, and it is very easy for an arm-chair psychologist to imagine that some sort of analysis is presupposed whereby these qualities are separated from the others. Such analysis, however, gives no evidence of its presence in the subject's consciousness. If anyone thinks that he makes the facts clearer by saying that the analysis takes place subconsciously, we shall not object. We merely

insist that this analysis is not, in these cases, part of the abstraction process as conscious fact. Our problem at this point, then, is to discover the cues or motives which lead the subject to assimilate the object perceived to some concept.

This assimilation is rather "rough and ready", apparently "intuitive." (We shall see that the intuition is prepared for.) In defining more carefully the exact conceptual meaning of the object, an explicit analysis often becomes necessary. But the analysis in this case follows the conception, whereas, in the cases just considered above, it precedes. In what follows, it has been assumed that essentially the same sort of process is involved when a certain feature is treated as a representative of the whole situation, and when the whole situation is taken as a particular instance of a more general category. This has been the traditional view and Avey (**4**) has recently found justification for it.

1. *Assimilation by Translation into other Sensory Modalities.* —It is, perhaps, only in those cases where the two senses must present the situation in quite widely different terms that translation from one to the other leads to assimilation. The whole process can be made clear by a concrete example. The common element which stood in one-to-one relation with the term *Bekis* in Group *a* was "circularity" or, more accurately, "curved geometrical figure-ness." Upon being shown *Bekis* for reaction in the second reaction period, subject W. wrote: "I had a motor image, which was that of moving my hand in a circular direction." She had seen with *Bekis* a circle and an ellipse. Her motor imagery was not fine enough to represent the differences between these two figures. Instead it could only represent the grosser aspect common to both presentations. Through the translation to motor imagery there has occurred precisely that emphasis upon the common element of two objects which leads to their assimilation to a common class.

The same subject began a very interesting development when she first saw one of the flower pictures called *Fefiv*. The particular flowers were hyacinths. She writes:

*W., *a* I, 2. "I first had an auditory image of the word fragrant, as I had said this to myself in connection with the learning series. I think I had a slight olfactory image."

A little later this passes over into a distinct olfactory image.

W, *a* III, 3. "This first gave me an olfactory image of the smell of flowers (I can't tell what kind)."

*W., *a* VIII, 7. "I had an olfactory image of smell of some kind of flower. Then I had an idea of flowers in general which seemed to get me all confused until I finally got the visual image of the apple-blossoms."

This general meaning of *Fefiv* as fragrant develops to the point where a presentation is rejected as a proper associate because not fragrant.

*W., *a* VII, 2. "I immediately got a visual image of golden rod. I had a feeling of dissatisfaction because I do not think golden rod goes with *Fefiv*; for the flowers that I connect with it are all particularly fragrant ones."

The process may seem to be analytic and to belong to the cues given above. As was pointed out there, however, whether a given case is analysis or assimilation depends upon the subject's attitude. If the subject regards "fragrant" as one of the many qualities of the object and seeks the others, we have analysis. In the cases here cited, however, this is not the case. Fragrant is looked upon as expressing the essential quality of all *Fefiv* situations, so that, as in the last protocol quoted, anything not fragrant is rejected.

Nearly all of the examples of this cue appear in the protocols of this same subject (W), who is the only one with a rich outfit of imagery in practically all the sense modalities. One may note also a protocol from An., *a* XVIII (*Cipuj*), which seems to belong here: "The filling pattern seems 'full', has tactual value." The complexity of this pattern was, as a matter of fact, its chief distinguishing mark.

The following two quotations from J. show incipient assimilation which presumably met with negative instances, since it does not develop.

c VII, *Wej* (*Dut, Yol*). "I remember that during the presentation period, the picture (perhaps its color) gave me the feeling of something cool."

c X, *Bef* (*Laj*). "During the reaction period (not upon first presentation) I followed the outline and thought of a dog at home."

2. *Assimilation by Translation into Feeling Terms.*—The essential principle is almost exactly the same as in the section just preceding. Not only this, but it is doubtful if some of the protocols here quoted do not belong there. The subjects are not unlikely to use the term 'feeling' rather broadly. We have accordingly brought together here not only those cases where the general meaning consists of feeling in its strict sense, but also those cases where the general meaning is so vague as to be described quite untechnically as a "feeling." This feeling stands as the general meaning of the exposed word, just as the olfactory imagery of fragrance or the motor imagery of a circle stood for the general meaning of their words. In short, we are dealing here again with the representative function.

An., *a* III, *Fefiv*. "First came a feeling-tone of lightness and delicacy attached to the term; then the verbal image 'flower'; then the visual-verbal image of the lilies."

It is uncertain whether the next two protocols belong here or not.

*S., *b* III, *Tugic*. "In kinaesthetic terms, 'that meaningless, unmusical piece', so designated since I was unable to catch a single word, and the roughness of the auditory impressions was decidedly unpleasant."

J., *c* V, *Yol* (*Miz*). "The sight of *Yol* made me associate it with a large, massive, strong object, which brought to mind the elephant." Here the association is apparently due to an organic kinaesthesis-complex, only with difficulty distinguishable from a feeling. A hint of one way of forming analogies is given us.

3. *Assimilation by Apperception of Use.*—The functional psychologists have done good service in calling attention to this process, though their insistence upon it as the essence of conception and abstraction is certainly one-sided. Use is a more general category than the individual percept. We may use quite

different objects for the same end. Hence if an object is perceived as "something to drink out of," a concept is involved, the object has been assimilated to a certain category.

There are only a few instances in the protocols of this sort of process. Indeed, except for the sets of "musical instruments" and of "utensils to hold liquids" in Group *a*, there were no objects which lent themselves readily to being thought of as useful. Under ordinary conditions, this form of conceptual assimilation must be much more common. The only cases relate to the *Xugic*-set, the liquid containers. In the case of the "musical instruments" set, if their use was part of the concept, as seems altogether likely, this aspect was not at all prominent.

W., *a* IV. "The image of holding a receptacle to drink out of;" and the subject adds what would make a good example for section 1—"not visual but rather in tactual terms."

The next is a mixed instance, but the concept of use is, nevertheless, very clearly present. It shows how the particular becomes general by apperception of the use to which it is put, and the case is in nowise hurt by the fact that the process is hastened by translation of the visual into motor imagery.

W., *a* V. "The visual image of the glass came immediately (reacted). This was followed by motor images of the movements I should make in taking up something and drinking from it."

*W., *a* VI. "A visual image of the glass in which the curves at the top were most conspicuous. There seemed to be at the margin of consciousness the idea of something to drink out of; I'm not certain, but I should say it was in motor and visual imagery. (Act of drinking.)"

C., *a* V. "Reacted to 'attitude' followed by auditory-motor image of word 'drinking'."

In all three cases, the concept is too narrow; but when an instance is found which will not fit, the concept is altered as little as possible. Thus, as will be seen in the following protocol, the use-concept is retained, slightly broadened.

*C., *a* IX. "Auditory-motor verbal 'Drinking vessel'. Feeling thas the word is not defined by this meaning. More clearly defined it meant something to contain liquid, but this is an after-thought."

4. *Representative Assimilation.*—In order to render it more manageable, a complex situation is often, as we saw above, broken up or analyzed. This is not the only method. In the protocols we have to deal with here, the subject selects some feature (usually the most prominent or the most essential) to stand for the whole, and this is dealt with as if it were the complete presentation. This implies partial disintegration, but not a conscious analysis of the situation. Indeed, the attitude of the subjects is entirely different in the two cases. In true analysis, we get the tendency to handle the situation in small bits and to follow up to the relations of each feature. In the cases we have to consider, the subject's tendency or avowed purpose is to deal with the situation *as a whole*, and the one feature is chosen because, as a representative, it makes this possible.

W., *a* XIV, *Dojaf*. "I had a visual image of a little white circle, and immediately I knew it was a graphophone, for this little white circle was on the horn of the machine."

W., *a* XVI, *Wocag*. "Then I tried to get a visual image and all I could get was something like this: two lines forming a right angle, although it meant rectangle to me."

Av., *b* VI, *Livab*. "Piece which starts with a whistle; I don't know any name. I find myself looking for something to hold to for identification."

S., *b* III, *Xugic*. "A more definite kinaesthesis appeared, to indicate a particular piece whose name I do not know but which was, I think, a quartet."

S., *b* VII, *Livab*. "The reference was to one of the phrases in the song which I could make nothing of except 'Wiggle de cag'."

Subject J. writes, in *c* VI, *Kuc*, of "the rectangular one with cut-out sides;" and later, in *c* XVI, *Kuc*, "the cuts in sides of picture in the image as also in presentation period seemed to me to belong to *Kuc*, and *Kuc* to them."

Mn., *c* X, *Bef* (*Laj*). "I know that it was a picture that was a brownish color and had a little figure of a rose-bud in the center of it. I am quite sure of that, for I have been in the habit of associating the syllable before with that little red figure in the center of the picture. I remember having recognized that this morning."

A definite sub-class is constituted by those cases where the blurring of the image leads to conceptual assimilation. A vague, confused, or incomplete image can be identified only as belonging to a certain class or group. Its individuality is lost. Although "logic-mongering" psychologists have often talked as if this were the only type, comparatively few cases occurred. The subject cannot at first identify the "fragrance" as the odor of any particular flower. The motor image is too crude to represent a circle or an ellipse; it represents curved lines in general. Many of the "feelings" are almost certainly such vague images in complex settings. We have brought together here, however, chiefly those protocols in which the assimilation is not helped, as in these cases, by other cues.

*An., *a* X, *Dojaf*. "Prompt meaning of musical instrument, not in visual-motor verbal terms, but a faint kinaesthetic attitude towards a semi-circle of schematic instruments surrounding me, *very* schematic and faint. The image of the piano came, rather non-significant, just as I reacted."

*An., *a* X, *Xugic*. "Blank with mere recognition of the term as such. Then the visual motor verbal image (fruit). I then reacted; but as I was reacting the real meaning 'butted in' carried by a visual image of some sort of receptacle and thus of the bucket. So far as these new meanings come, they seem to come by means of a fading away of the outline and colors into the fringe, leaving the pattern in bold relief."

C., *a* III, *Dojaf*. "Reacted to verbal imagery 'musical instrument' and vaguest sort of visual image of the instrument (I don't know what)."

W., *a* IV, *Hexur*. "My idea of soldier seemed to consist in a visual image of a soldier's arm supporting a gun; the rest of the figure is gone."

W., *a* VII, *Vupaw*. "It consisted in a decidedly mixed-up mass of visual images of different fruits and some gustatory images of the same."

5. *Assimilation to a more General Class through Failure of the Particular*.—Only three good instances of this class were found, but all are quite unequivocal.

W., *a* VII, *Wocag*. "I had a visual image of the geometric figure; I could see it ever so plainly, but it was an appreciable time before I could seem to think of trapezoid. (When I did it was in visual verbal terms.)"

It is perfectly clear what happened here. The image was a particular, but the subject found it a little difficult to name, trapezoid not being a name one uses often. Before she could recall the particular name, the general class name and its concept—viz., geometrical figure—occurred spontaneously.

C., *a* IV, *Bekis*. "Vague visual image of a curved geometrical figure followed by auditory-motor image of word 'curve'."

Much the same process is here going on. The *Bekis*-figure shown in sitting IV was the curved figure without any name. Now subject C. in these experiments remembers chiefly by visual and motor verbal, supplemented by a concrete visual image. In this case his verbal "tag" is lacking. Hence a failure of the particular to appear and the instancing of the general. As regards the image, of course, this protocol resembles the cues of the "blurred" image class.

Very similar to the last is the following:

W., *a* IV, *Wocag*. "There seemed to be a moment in which I was conscious of nothing save just knowing that word. Then I thought of geometry (which consisted in a visual image of certain pages from a Geometry book). This developed finally into a visual image of the triangle."

There can be little doubt that this sort of cue is more frequent in real life situations than under our experimental conditions.

6. *Assimilation by Immediate Association of the Situation with a Class Name.*—The connection between class names and concepts is so intimate that an association of a situation with the name is tantamount to assimilation, if the concept and the situation are not irreconcilable. For all that, the class is, it must be confessed, somewhat unsatisfactory. The main difficulty arises from this fact, that "immediate" associations are usually either impressionistically reported associations or associations with a history. Yet if the following protocols be examined one by one, a certain degree of uniformity will be found to justify their being grouped together.

*C., *a* IV, *Bekis*. "Reacted to 'attitude' followed by auditory-motor image of word 'curve', followed by visual image of circle on cream background."

*W., *a* VIII, *Vupaw*. "I think I had only a visual verbal image of the word 'fruit' in this connection."

*W., *a* VIII, *Dojaf*. "I knew this had something to do with music as soon as I saw it. I said to myself, 'this means music,' but it was not till some time after that I connected it with the piano."

J., *c* IV, *Gej* (*Laj*, *Kuc*). "The sound of the word elephant was heard while thinking about syllables and I sought to find reason for it. The picture, in brown and tan, occurred which, on first sight, resembled a picture of an elephant."

An interesting sub-class, if not a special group, is constituted by the following protocols. In all of these, the syllable recalls two images, both of which can be designated only by their class name. No doubt the presented object, the picture, had been assimilated before the reaction, though we cannot be sure. It does not follow that there is no gain. The simultaneous presence of the two images, and their designation by a common name and by a single nonsense-word, prepare the way for the nonsense-word to become the name of an abstract quality.

*W., *a* IV, *Dojaf.* "A visual image of a grand piano, followed by a visual image of a victrola (with a horn). Reaction given with image. The idea of musical instruments seemed to follow the two previous images."

*An., *a* IX, *Vupaw.* "Fruit. Schematic visual image of a pile of mixed fruits apparently brought meaning. Later came particular image of bananas. The term 'fruit' came, I think, in visual and motor verbal imagery terms, but very fleeting and faint."

Still less than in the case of the cues to analysis is it pretended that the above cues to conceptual assimilation are exhaustive or adequate. The greater number of the experiments were designed to bring out not the conceptual but the analytic approach to abstraction. Fortunately, since there are thus fewer examples, the types are more sharply defined, there is less overlapping. Yet that the above classes represent more than divisions of convenience can scarcely be maintained. The fact that these divisions *are* convenient, however, shows that the classification is not entirely arbitrary.

Nor is overlapping entirely absent. The first two sections clearly belong together. The nonsense-word is associated with something other than the primary data, with other kinds of sensory images or "feelings." This leads to conceptualization by emphasizing the only quality which unites the two forms of presentation, which is common to both because they are both instances of it.

The cues of the next section (through apperception of use) have this in common with the first two, that they too deal with transformations of the primary data, and that the transformation again brings out that which makes it possible—a more general category.

Blurring of the image and representation belong, similarly, to another group. In these two some one aspect of the primary data is emphasized. In the one case, it is the only clear or "visible" aspect, in the other it may be one deliberately chosen as the representative. In both cases, the emphasized quality is one which unites the presented object to some relatively stable mental category. The two forms often cooperate. Standing between these two classes and the three previous are the cases where a verbal term acts as representative of the primary data. For the name is distinctly "felt" to be a representative rather

than a transformation of the presentation, so closely is it connected with the objects it symbolizes.

All of these classes are of such a nature that, although they involve a developed consciousness with pre-formed mental categories, yet they can assist in developing new categories or in modifying old ones. In the cases of Assimilation through Failure of the Particular and by Immediate Association to a Class Name, this is not true. The cues lead the particular over into the general, but do not take any part in modifying either. They presuppose very definite classes, and classes which moreover have previously included just such objects as the present ones. These two classes, therefore, are clearly much less fundamental than the other five.

A noteworthy point is the relative lack of importance of language in this conceptualization as compared with analysis. A casual reading of the logical treatment of conception would lead to the belief that concepts and terms are identical. And while this extreme position is probably held by few, language is considered a fundamental part of the process by practically all logicians. It can be seen from the above that such is not the case. In most cases, its functions are the strictly secondary, although still very important ones, of clarification, definition, and fixation of concepts. Only seldom did it play a great part in the modification. The point illustrates not so much the divorce between psychology and logic as the necessity for psychology to make an independent study of processes also dealt with by logic.

The Further Development of the Process

The development of the process of abstraction is necessarily somewhat different, according to whether the first phase ended in conceptualization or in analysis. Conception is obviously very much nearer to a complete abstraction, so much so that at first thought they seem to be identical. But they are sharply divided in fact by a difference in the subject's attitude.

In the one case, the subject views a presentation more or less in its entirety as a member of a certain class, which class is named by the nonsense-word accompanying it. The concrete details of the situation are far from uninteresting; it is rather the concept which is dull. One subject (W.) complained of the *Hexur* (soldier) group that diversity was almost lacking, while in the *Fefiv* (flowers) group there was an interesting variety. The same subject explains that she is not satisfied with knowing the general meaning of the term, but wants always to know what particular *Bekis*, *Dojaf*, or *Hexur* was shown in the current sitting. It can hardly be said, therefore, that there is an abstraction of all save the common concomitants of the given word, although the word is clearly the name of a class-concept.

(Compare the remark of W. in *a* XVI: "I believe if I were to meet a soldier on the street, I'd call him a *Hexur*; *Hexur* and *Fefiv* are now regular words for me.")

Yet we have said that conceptual assimilation may serve as a first step towards abstraction. In this way: the "nonsense-word" becomes firmly associated through such conceptualization with precisely the only relevant quality. The abstraction does not take place, however, until the irrelevant is recognized as such, and this is a step in advance of assimilation to some mental category. How that step is taken, what are its cues, to extend the term used above in a slightly narrower sense, the data of these experiments do not enable us to determine completely. Of one thing we may be sure, that relative familiarity of the concept is unfavorable to this change of attitude. Where the concept is easy, familiar, simple, the attention of the subject is turned towards differentiation; where, on the contrary, the concept is relatively new or recently modified, where its boundf aries are as yet but ill-defined, the subject will be impatient o-all save the essential qualities of the concept, for it is these which will serve to differentiate it from others. Hence we find, with subject W., that the very much more difficult new material of the second half of Group *a* leads to an abstraction from the non-essential details in half the time taken for the easy, familiar objects of the first half.

Another factor which helps to change the attitude is what we shall have occasion later to consider under the name of "associative abstraction." The subject finds himself unable to recall aught save the essential quality. This is not yet a full-fledged abstraction, but if he recognizes this *as the essential quality*, he is led to think: "After all, what does the rest matter?" These are the only hints of the cues which cause the change in attitude from conception to abstraction. It will be remembered that conception as the first phase of abstraction was predominant only in the protocols of Group *a* and was not there exclusive.

We can trace the change from analysis to abstraction better in the protocols of Group *c*. In the case of only two subjects did this change spontaneously occur. We must take up their protocols in some detail; but before we do so, a general statement will help to orient us in that study. The change from analysis to abstraction is sudden, apparently intuitive. Now to call a change 'intuitive' is to challenge the psychologist to trace its genesis. We must seek, then, for changes in the protocols which belong to the level of analysis, but which tend to lead the subject away from that level.

We can trace the process most easily in the protocols of subject W. This subject did not approach the experiments of

Group *c* quite unsophisticatedly. She had been subject in Group *a*. More important than this, she knew that the "pictures" were to be made out of wall paper. The latter fact provided her with a ready-made, though not quite complete analysis. The former fact influenced her reactions in several ways. First it undoubtedly caused her immediately to look upon two syllables as the name of the picture with which they were given. That at first the two syllables were considered to be a unit, one name just like John Brown, is obvious from her remark at the end of the first reaction period: "It is very clever of you to make us introspect twice on each picture." That is, each syllable was felt to be the equivalent of one of the nonsense-words in Group *a*. This substantiates the subject's subsequent report that her *first effort had been to keep the two syllables together*.

Her familiarity with Group *a*, particularly with the last three sets, also undoubtedly helped her in her analysis of the figure; helped her primarily, it seems to us, by providing her with the appropriate categories and thus suggesting the lines of division her analysis should take. True, all of the subjects have such categories as pattern, color, form, but they do not bring them into relation with the experiment so immediately. In almost every one of W.'s protocols, one or the other of these categories is used. In the main, this seems to have been reflectively determined; but it was certainly aided by the memory cues to analysis and to no small degree by the attention cues. Two things were particularly striking: the little figure in the *Bef*-pattern, and the red of the *Gej*-pattern. The *Wej*-pattern was also fairly well noted, but the other pictures were merely "those brown ones."

The process as it took place in the first sitting seems to have been as follows: first, a temporal analysis as attention passes from aspect to aspect according to the regular laws governing it; secondly, the assimilation of the aspects thus separated to various mental categories (largely provided by the experience of Group *a*) and the adoption of the analytic attitude, the "set" to apprehend the presentation in more or less elementary pieces (of course these two processes are not temporally separated); thirdly, the "fixing" of the analysis by differential memory for various elements and by the necessity of making a report.

During this first phase, however, the subject has no idea that the pictures are artificial synthetic products of these elements. They are thought of as unities which decompose into, rather than are composed of, the elements. And it is essential to notice that at this stage the two syllables are regarded as really one, a name applying to the pictures as unities.

The next step is a change in the attitude towards the syllables. The effort to keep them together breaks down. The subject is forced to recognize their mutual independence. This process begins in the second sitting. Certain of the combinations are remembered from the previous sitting, especially those making rhymed or otherwise euphonic combinations, such as *Wej, Laj*. This combination is not met in the presentations. Instead another context is found for each syllable. For instance in sitting II, *Wej* appeared in two combinations as *Wej Kuc*, and *Wej Dut*. The subject writes on being shown *Wej*:

"First an auditory verbal image of *Wej Laj*. I then said to myself that those went together in sitting I; but I was very doubtful about their being together this time. I felt that there was another word in place of *Laj*, but when I tried to think of it I did not succeed. *Wej Laj* just rang in my ears, and it didn't seem as if anything else could go with it."

Or again, when shown *Laj* a little later in the same sitting:

" 'That goes with *Wej*.' An auditory verbal image of the two. Also a visual verbal image. I said to myself, 'they go together anyway, even if I didn't have them today.' "

Simultaneously with this there has started another process relating to the syllables which is of great importance. Merely as an aid to the recall of the other syllable, the subject asks herself what was the position of the given syllable in its pair. Even in the first sitting this device was three times resorted to, and in the second it becomes a part of the regular procedure.

This gradually alters its nature. Instead of merely "first in its pair," the syllable becomes "one of those syllables which come first in the pair." The step, which is a most important one, seems to have been taken towards the end of the second sitting and during the presentation period of the third. With this subject, we have no evidence in the protocol how the transition takes place; the classification appears suddenly as a fairly-well established hypothesis. This hypothesis outruns any substantial inductive basis for it, but was explained by the subject at a later period as due to a desire, which could not be repressed, "to beat the experimenter's game." If the syllables could not be kept together, evidently the experimenter meant to keep them strictly apart. Then on what basis? For the first two sittings certain ones were first, others second. Very well, this would serve provisionally for classification. In line with the general plan of the whole research, to give the subject few instructions and to approach as much as possible the conditions of real life, no negative instructions were directed against this attitude.

Having now two classes of syllables independent of each other, what more natural for one who takes this attitude than to seek the things to which the syllables refer? For we have seen that they were from the start regarded as names. Since they cannot

be jointly one name, they must be severally two names. At this point again we must see the very great influence of the subject's previous knowledge. She knew, as has been said, that the pictures were cut out of wall paper, a fact which suggests that the shape and the appearance of the paper are important items *as elements either to be associated or to be neglected.* For, in Group *a*, certain patterns whose color and outline varied irregularly had been given a nonsense-word name, while other nonsense-words were applied as names to outlines (not generally the same as used with the patterns). The subject thus has the categories to which nonsense-word names have been applied by the same experimenter under similar circumstances, and her analysis of the presentations has provided instances of these categories. Pattern and color are not always sharply distinguished from each other but are collectively called "wall paper." In the first protocol, however, where the hypothesis appears, the contrasted elements are pattern and outline.

III *Wej* (*Yol*). "First I remembered that this syllable came first. Then I tried to think of the other one, too. I had a visual image of *Yol.* Then after that I had an auditory image of the two syllables. Then I tried to think of the figure that went with it. I said to myself 'That first word has something to do with the pattern of the paper, not the shape of the figure', so I tried to think which wall paper was used. I got a visual image of wall paper made of fine lines going horizontally in gray and yellow. Then the image seemed to take on an outline rather distinct, which makes me think somewhat of an elephant. Then I said to myself 'No, that isn't right, for if it is one of those papers it was covered with either fine pink or fine blue lines', but when I thought of those it did not seem as if they had gone with the word *Yol*, so I thought again of the first image I had had. This seemed right for *Yol*, but I was not sure of it for the other word. However I reacted."

Questioned as to why she thought that this syllable was connected with the pattern rather than with the figure, "the subject could not give a satisfactory reply but added, 'I was beginning to form some associations now between the last syllable of the two [in each case] and the shape of the figure'."

It is impossible from the protocols to trace the exact genesis of this hypothesis. Kant seems to have meant this sort of thing when he spoke of the representation of a method, Husserl calls it categorical intuition (kategoriale Anschauung), while Bühler (5) has subjected it to some degree of experimental analysis under the name of "Regelbewusstsein." Yet no one has, so far as the writer is aware, directly attacked the crucial problem of what it is that leads us to propose certain hypotheses to ourselves for experiential testing. It is precisely because our own experiments enable us to show only *that* and not *how* analysis and conception pass over into abstraction that this study has been limited to the initial phases of the last-named process.

We may be permitted, however, to watch the development a little further. One interesting point is this subject's procedure from class to member of a class.

W., III, *Jid* (*Laj*, *Nud*). "First I said to myself, 'It was probably one of those brown ones?' Then I thought, 'No, today the papers were mostly colored.' Then I had a visual image of the pink paper."

W., *Gej* (*Yol*). "First I said to myself, 'Now that was the last syllable.' Then I decided that it wasn't the last syllable, but was one of the first, and so referred to the paper rather than the figure. Then I had a visual image of the red wall paper. Here I reacted. After reacting I got a visual image of the wall paper in this form [drawn]."

W., VII, *Gej* (*Nud*). "First I said to myself, 'Now that syllable goes with the wall paper'. Then I asked myself what wall paper it was. First I thought of the wall paper that is made of rather broad stripes, some of it is red and some of it is brown. Then I said to myself, 'No, that isn't right.' Then I thought of the wall paper in which the figure is made up of fine gray and pink or gray and blue stripes. But I said again, 'No, *Wej* goes with that wall paper.' Suddenly I had this visual image. It was a blue wall paper made in this form: [drawn]. Then the paper seemed to be in this shape: [drawn]. Here I reacted. Just as I reacted I got a visual verbal and also auditory image of the word *Laj*."

Another point of great interest is the fact that although from the third sitting on the subject is always aware that a certain syllable refers to or names only a certain element, negative abstraction takes place to only a small degree. It will be remembered that Külpe (**10**), Grünbaum (**8**) and Moore (**12**) all found that the greater the positive abstraction, the greater the negative. This was due, however, to the common experimental procedure of all three. The result of their instructions was in each case the more or less conscious "Aufgabe" at work upon material possessing little or no organic unity, and could not fail to result in a positive repression of the "unessentials". Our subjects, being left to themselves, followed their own bent. Subject W., while recognizing perfectly the one-to-one relation of the syllable and the presented element, does not consider the other elements as uninteresting and constantly endeavors to recall them.

The case must not be confused with the same subject's tendency in Group *a* to recall all of the various individual "pictures" with which a syllable had been presented. This we denied to be abstraction on the ground that the attention was on the denotation rather than on the connotation of the syllable, as was there required for abstraction. The subject's attitude was perceptual rather than abstractive (see above, p. 38). In the cases now under consideration from Group *c*, the subject is very much interested in knowing what other syllable and pattern had been present with a given shape, say *Kuc*, but these accompaniments are clearly recognized as having no influence on the nature of the *Kuc*-outline or on the meaning of the syllable.

The other subject whose insight came very quickly was El. He started with no such foreknowledge of the problem as W., but he seems from the first to have been unable to repress a tendency to speculate. In the fifth sitting, it became very obvious that his reactions were no longer unsophisticated. Accordingly, after the ninth protocol, he was questioned as to the reaction for the association he had reported.

Question: "What makes you think that *Kuc* is to be associated with that figure?"

Answer: "Because during the initial exposure today a hypothesis, which I have been suppressing, became very dominant, namely: that the second of the two syllables is the one which means the figure associated with it, while the first of the two syllables means the color of the same. It is evident that in all the introspections given today this 'Aufgabe' is controlling me. The hypothesis appeared today very suddenly, as if the

thing had been forming in my mind unconsciously since the previous experiment day, and not at all as a result of this morning's exposures. These exposures, however, have not served to disprove the hypothesis, even if there is considerable doubt of its proof in my mind. This came so suddenly and with such a feeling of success that I am reminded to add that it was present on the first exposure of the series, *i. e.*, of today, and was not at all the result of a deduction formed during the exposures this morning." Later he spontaneously adds: "As near as I can get the first flash of insight, it consisted in remembering that the *Yol*, particularly on the very first exposure of the first series, had always been associated with the 'polar bear'; secondarily, but far less near, the association between *Miz* and the brown with the faint green stripes running through it seems also to have played a part in forming this definite conviction that this is the 'Aufgabe' controlling the experiment."

This reply serves to orient us as we take up the detailed study of his progress from day to day. Especially it behooves us to take particular notice of the protocols concerned with *Yol* and the *Yol*-'polar bear' figure. Of the presentations in the first sitting, little was correctly recalled in the reaction period except *Yol*. The *Yol* outline had been seen twice with *Bef* and with *Miz* patterns, the former being the first presentation of the whole group. When *Yol* was shown for reaction, a fairly complete report was given; *Bef* is recalled to the left of *Yol*, the figure is likened to a polar bear, the brown color is prominent. *Miz* recalls *Yol* to the right with the brown polar bear in the background. *Bef* recalled *Yol* (no order is mentioned) and a visual image of the brown polar bear of which the "head" is clearest.

In the second sitting, *Yol* was seen in a *Gej* pattern of a striking red color. *Gej*, however, fails to oust *Bef* as the associate of *Yol*, but the color of the "polar bear" fluctuates between brown and red, finally settling on red. This sure association of *Yol* with the "polar bear" figure together with uncertainty as to color is very significant. The dissociation of color as being referred to by *Yol* distinctly begins. To some extent in sitting I, and very noticeably in II, the analysis of the pictures is proceeding by the cues of Differential Memory amd of Characterization. *Miz* is incorrectly associated with a *Wej*-pattern.

In the third sitting little that is new develops. Few of the syllables recall correct or at all accurate associates. *Bef* continues to be recalled as the syllable associate of *Yol*. The combination of *Bef Yol* is firmly fixed as the associate of the polar-bear figure which appears with "various colors competing." It is strange that with *Bef Yol* so firmly established, no shock was felt when *Wej Yol* was seen. The analysis by the various cues, chiefly Memory and Characterization, has proceeded so far that "form" is distinguished from "color," but "color" is used for the colored pattern.

Sitting IV shows notable advances. At first *Bef* is recalled by *Yol*, which also recalls the polar-bear figure with alternative

colors. When *Bef* is shown, however, the subject recollects that in spite of his immediate recall of *Yol* and the polar-bear figure, *Bef* has been "in an association with other syllables with other figures, but am unable to say which." This is a point of very great importance. The *Yol*-figure is already clearly separated from its accidental concomitants; but, so long as *Bef* and *Yol* are kept together, the abstraction of all other qualities except a certain outline as associates of *Yol* could not take place. Meanwhile, as with subject W., a division of syllables into left-hand and right-hand syllables has been effected. The subject is getting more familiar with the pictures and recalls them more accurately.

Sitting V was the critical one, as the subject's general report cited above indicated. The *Yol*-outline was again the first one shown. *Yol* had in the four preceding sittings become firmly associated with this figure and in the last had thrown off *Bef* as a constant associate. When the figure reappeared in a "new" color and with a "new" syllable, the supposition that the last syllable corresponded just to this outline became unavoidable. We may discount the subject's insistence that it was present at the beginning of the sitting, though some vague inkling may have indeed been present. From *Yol* as referring to a single outline is but a short step to a complete schematization, since as Bühler (**5**, 338) has shown, we form "Regelbewusstsein" with extraordinary facility. All the necessary facts are in the subject's possession: two classes of object-elements, two classes of syllables, and in one case at least a well-established one-to-one relation between a member of one class and a member of the other. The subject somewhat hesitatingly ascribes to a fairly constant association in his mind between *Miz* and its pattern some part in building up the hypothesis. This is so far from being true that *Miz* had previously never recalled its proper pattern. The hypothesis is thus based largely on a single instance *plus* a vague consciousness of the other instances. The subject at once sets to work to test this assumption by the method of agreement and difference, and finds, on his own showing, at least no disproof. In the fourth and fifth protocols of sitting V he announces his conviction that in each case only a color or only an outline is relevant. At the next sitting, two examples of one pattern in different colors bring home to the subject the difference, of which he was already half conscious, between color and pattern. With the formation of this hypothesis, abstraction has clearly taken place.

As before, however, it is worth while to notice a few further points. With this subject, the procedure from class to member of class seems not to be so common as with W., and one may add as with An. Rather, as he says later:

"I appeared spontaneously to wait for the appearance of visual images. When the reference of the syllable is to the left, the first sort of image to appear is usually that of the pattern. Sometimes it inhibits the appearance of any form image and sometimes it doesn't. Usually the pattern image appears before I get the realization that the syllable refers to it, and not *vice versa*."

To the extent that this is the case, it is probably due to the fact that the syllables were less clearly or rather less emphatically divided into two classes. Before he realized to what they referred, Subject An. greeted each syllable with a kinaesthetic jerk, placing it to the right or left, while W. reacts with the verbal kinaesthesis "first" or "second". Neither of these tendencies is found in so pronounced a form with El.; the position of the syllable until after the hypothesis was formed was rather an indifferent detail. Even so, the procedure from the consciousness of the class to the consciousness of the member of the class is by no means uncommon.

El., V, *Gej* (*Laj*). "Introspection shows this 'Aufgabe' governing my search for a color to be associated with *Gej*. This search was unsuccessful unless it be the case that the finally found color, red, is the one which seems to be most probably the correct one. The process of search consisted of running over in my mind the various colors with rejection. Such colors seen were the blue and silver stripes, the brown with the squares of black lines, the brown with the faint green, irregular markings and, finally, the bright red. In the background of my mind was the phrase, 'episodic connections' (between these various colors and the figures involved). In particular the blue with the silver stripes was associated with the vest-shaped figure as I think they were given in the exposure this morning."

VI, 1 *Nud* (*Miz*). "The first datum was the knowledge that this syllable is the second of a pair. In recollection of the theory formed last time this immediately led me to search for the shape of the figure, which appeared fairly distinctly as the figure pointing toward the upper left-hand corner. The consciousness of a peculiar color in which this figure appeared for the first time this morning. The backward association to various syllables was rather prominent, *Bef* occurring repeatedly."

That the hypothesis or "Aufgabe" controls the subject's reactions in ways of which he is not himself conscious is seen from the following fact. Although the subject often made errors after this, he never assigned a pattern word to an outline or an outline word to a pattern.

Negative abstraction becomes increasingly greater with this subject. Images of form are inhibited when the stimulus word is a pattern syllable. In part, at least, this is intentional, in part it seems to be automatic.

We may introduce here points gleaned from the protocols of subject An., who alone of the other subjects attained a fairly complete abstraction. Indeed, having advised the experimenter upon points of procedure, he knew the problem too well to adopt anything but the abstractive attitude, and all his protocols therefore were taken after the point chosen as the limit of our study proper had been attained. We have, it is

true, cited many instances of the cues to analysis or conception from his protocols, but these cues occur as parts of a finished product and could not be given their proper setting in the process if all the subjects had attacked the problem with the same degree of sophistication as to its nature.

It is interesting to notice, however, certain further developments. This subject practically always first assigned the stimulus syllable to one or the other class before associating it to a particular member of the class. In most cases, unless the class could first be determined, the individual associate was entirely inhibited. Negative abstraction was very marked. The subject seemed almost annoyed if he got a visual image of anything "irrelevant," an attitude in striking contrast to that of subject W. On the other hand, in those instances where a pattern-word recalls an outline-word, the latter controls the immediately subsequent reaction and the subject gets an image of a form, *then* of the pattern on the form. The contrary process is not found at all often. In other words, the subject can more easily abstract from the outline. As between color and pattern, decision is not so easy; but it seems likely that patterns, at least the sort of colored patterns used in this experiment, are more easily abstracted from than color.

The progress of the remaining subjects in Group *c* towards complete abstraction was much slower. This has, for our purpose, certain advantages which serve to offset the disadvantage that none of them finished in the number of sittings which could be given to this experiment.

The first is the bringing into clear relief of a process which would otherwise have remained obscure. It depends for its efficiency upon the law of frequency of association. Certain features have been seen with every exposure of a given syllable while other features varied. Thus is established between that syllable and that feature a stronger association, and though the others are forgotten, this one feature is remembered. We shall return to this process later.

The second advantage of the slower progress is that we may by comparing the two groups of subjects throw additional light on the mechanism by which one advances from analysis to abstraction. Differences in detail will be noticed when we take up the different subjects singly, but one great difference may be considered here. It is difficult to characterize it in a word, but one may say that the subjects who did not attain to abstraction attacked the problem *unspeculatively*. They were not trying to "beat the game," but merely endeavoring to make a report in accordance with instructions.

With subject P., the difficulty of making a report was sufficient to check any speculative tendencies for some time. His

whole effort was directed primarily to "finding" the companion syllable of the reaction word; next and less important, its companion picture. In general, his imagery reproduces the presentations rather poorly, even the verbal associations being more often wrong than right. The analysis by differential memory makes only comparatively slow progress since the subject strives constantly for total recall. By the end of the sixth sitting he has advanced only so far as to realize that the various shapes have different "colors" at different sittings, and that the syllable pairs are not constant. This last fact becomes of engrossing interest to him; his whole effort is devoted to recalling, and if possible dating, all the syllables which had ever been presented with the given reaction syllable. The subject explicitly states this as his "Aufgabe" in this sixth and the seventh sittings. Visual images are present only incidentally. It seemed that such exclusive preoccupation with the merely verbal must be broken up. Accordingly preceding his ninth sitting, the following comment was given him to read: "You are away off. You have been verbally associating one syllable with another, making a pair unit. Just remember that each syllable alone means something specific—which is not another syllable with which it may have appeared." The result was immediate. The subject reports:

"There seemed more of simultaneity in the coming of the syllable and of the visual image than ever before. The syllable and picture seemed to be there at once" (IX, first report). "In this instance there seems a strife between a verbal association with *Jid* as *Jid Dut* and a tendency to form the visual image with the single syllable *Dut*. There seems for the first time a tendency to run from the first syllable to the visual imagery" *Dut* (*Gej*). A marked improvement in accuracy of recall follows, in spite of rather poor physical conditions during this sitting.

Nothing in the way of systematization takes place, however, in the next three sittings; but two facts are laying the foundations for it. The reaction syllables in increasing measure call up the "picture" that day presented with them. This is due to several factors. The newness of the laboratory experience has worn off, all the presentations are familiar and, the excessive preoccupation with the syllables having been done away with, the subject is able to turn his attention to the figures. In some cases, although the picture as a whole is incorrectly recalled, the one particular feature referred to by the reaction syllable forms part of the visual image. Since the subject is as yet clearly unaware of any such relation, we must ascribe this to the associative abstraction of which we spoke above.

A second influence leading toward systematization is the recognition that a syllable has "gone with" two figures of different shapes but the same "color."

X, *Nud* (*Miz*). "There was present with it also the association of *Miz* with another syllable and with the same colored picture but a different

shape. The other syllable did not appear, but *Miz* was recognized as having been present twice with the same color, the differently shaped pictures."

Analysis by means of the various cues above described now proceeds pretty well, but the "Aufgabe" of full and complete recall of just what had been presented remains so dominant that all speculation is repressed. In the fifteenth sitting *Bef* is linked, apparently by associative abstraction, to its pattern but the cue is not followed up and no further gain is made.

P., XV, *Bef* (*Yol, Dut*). "This syllable *Bef* is associated with a certain visual image which appeared immediately. The shape of the visual image is not very distinct, but the pattern of the paper is. It is arranged in squares. This visual association came spontaneously and at once. The mind sought to force a verbal association without definite success. The only syllable that did come was *Bef Laj*, but there is no certainty that that is the one this evening. The association between *Bef* and the color of the paper is definite. There is somewhat of a dispute between two shapes for the visual image. One shape seems to be that of the parallel lines at the top and bottom with indented sides; the other the tall narrow picture. No definite certainty as to the shape, however, The syllable, *Laj*, did not seem to be associated with anything. It was the only syllable that appeared."

So near can one come to abstraction without reaching it. Sittings were unfortunately discontinued at this point.

Difficulties with the experimental conditions and consequent over-emphasis upon total recall prevented classification and, above all, speculation about the material, for this subject. This is the outstanding cause for his failure to reach an abstraction. Associative abstraction was in evidence, but its operation can be better studied in the protocols of S. and J., to the former of whom we now turn.

The attitude of this subject was marked throughout by certain uniformities. The first was the effort in the reaction period to reinstate the entire situation experienced with that syllable in the current presentation. Thus he endeavors to recall the associated syllable, the place in the presentation series, and the visual details of the picture. The subject's more immediate memory was thus very good, but he carries very little over from sitting to sitting, apparently because he makes no effort to do so. At any rate, things so remembered are neglected promptly—a very distinct form of abstraction, which, however, could not be studied.

A second feature of this subject's attitude towards the experiment was his effort in introspection to describe his experiences so far as possible in elementary terms, especially in terms of the kinaesthetic and organic sensations in which he does a great deal of thinking. Two examples from sitting V will make this clear:

"Promptly came creamy brown figure [drawn] with two smaller detailed figures on its face. It was accompanied by a general kinaesthesis, particularly of the upper part of the body, and a repetition of syllable

together with *Nud*, as *Bef Nud*. The kinaesthetic sensation from arm and visual image of hand followed. Reaction."

"There appeared a visual image of the green brown figure vaguely outlined, followed after a period by a creamy yellow figure [drawn]. Meanwhile a kinaesthetic complex was somewhat in opposition to it. It did not 'fit'. This was an unpleasantly toned complex which seemed to be a continuation of an expectation kinaesthesis. Verbal processes were vague glosses. The reaction was voluntary as before to end conflict."

This non-speculative attitude of the subject—for it is obvious that he has no place for speculation with all this detail to be attended to—was confirmed by one of those accidents from which even experimental work cannot be free. In the fifth sitting the *Yol*-outline was yellow. The subject noticed the combination Y—(ol)—Yellow, and though rejecting it as irrelevant used it as an associative link between the syllable and the color. Now although in this case wrong, this was a beginning toward an association between one of the syllables and one of the elements of the situation, which had by now undergone analysis in the manner above described. Had this tendency been further followed out, the subject would have undoubtedly arrived at an abstraction much sooner. But at the beginning of the next sitting, subjects were warned "not to use irrelevant associations" (see Appendix, p. 71, for details). Subject S. interpreted this to mean that he was to repress just such associations between syllable and features in the picture as that between *Yol* and the color, which he had at the previous sitting reported. The result is that the syllables are taken to refer to the picture as a whole. For instance in VIII, he saw the *Jid*-pattern in light brown ("white") with the *Yol*-outline and in blue with the *Nud*-outline. *Nud* had been shown moreover with the *Wej*-pattern. On being given *Jid* in the reaction period he wrote:

"Visual image came promptly but as it came there was a feeling as if something organic and kinaesthetic had preceded it, as if there were a preparation for it. The figure first appearing was the white [draws *Yol*] then the blue [draws *Nud*]. At presentation the two had become associated with a single syllable *Jid* and likewise distinguished from a white figure resembling the blue [draws *Nud*]. There was no hesitation in accepting the appearance of one or both as the appropriate meaning of the syllable. *Jid stands for either or both*" (author's italics).

The subject does not seem to have noticed the identity of pattern, but had he been searching for some element in the pictures to correspond to *Jid*, he could hardly have failed to notice it.

Analysis of the situation-complexes by way of the various cues is, of course, complete. In the fourth sitting, the subject tries to systematize the thing a little in the interests of memory, but his first hypotheses are not validated and he gives it up. Later, without any explicit reference to it, he returns to the task and does succeed in the presentation period; the pattern being

identical in the first and third, the outline in the third and fifth. This position-framework is recognized to be the same no matter what figures are given, and hence is again very clearly an abstraction. Unfortunately we cannot trace its development, since in relation to the experiment it was largely accidental. We can only say that it was set up in the service of the memory attitude, which continued to rule, and that the mechanism was a deliberate trial-and-error method.

Before the nineteenth sitting, the subject was asked to "give the specific reference of each syllable". The subject retorted that he had been giving it to the best of his ability. In the first protocol he wrote as addition to the usual report: "The figure was one of the things 'meant' by the syllable—other things were position, exposure period, repetition, setting down introspections, accuracy of description, etc.—the whole group of acts surrounding the perception of the syllable."

It is small wonder that with all of this the subject had not reflected upon the experiment. It must be insisted, moreover, that he had deliberately tried to repress all speculation concerning the problem. When, just before sitting XXI, he was told to find the specific reference of each syllable to some detail or feature of the "picture," he objected that he had been prohibiting just such associations, but that the meanings of at least four syllables had become pretty clear. How he could not say.

From the protocols, however, it is quite obvious how this has come about, namely, by associative abstraction. This has been at work theoretically since the second sitting. Actually its influence has been clearly observable since the ninth. In associative abstraction a firm bond of association is established between the nonsense-word and the element with which it has always appeared, while the varying concomitants are connected less firmly. The difference may extend from a slight emphasis upon the constants together with clear recollection of the variables to a very great emphasis upon the constants together with absolute inability to recall the variables. Where the variables are limited in number and themselves objects of interest, as in these experiments, it more often happens that the constant associate of the nonsense-syllable is correctly recalled while with it appears, not the variable of that sitting's presentation, but that of some other, perhaps quite a long time before.

It is clear that associative abstraction has a great deal to do with the memory cues to analysis. The latter, however, are more comprehensive, including as they do separation of the features of the situation in memory by whatever means, and emphasizing the separation of the different features rather than the connection of one of them with the nonsense-syllable. The outlines were more often thus "abstracted" than the pattern;

and apparently, though not so certainly, color stands between the two. The *casual* operation of associative abstraction is one of its striking features. Nor could anything else be expected. For in addition to frequency, other factors influence association, more especially recency and intensity of impression. Thus it happens that, at the end of twenty sittings, the "specific meanings" of four only out of ten syllables were clear to this subject, while the meanings of all the syllables were clear to one subject who used what we may call the intuitive method at the end of three, to another at the end of seven sittings.

Very much the same remarks hold for subject J. as for subject S. True, she did not attempt, as the latter did, a fine introspective analysis of her reactions. But to write a protocol at all was an entirely new task for this subject (who had had no experience in experimental psychology) and absorbed her best efforts in much the same way as the analysis into elements had absorbed those of S. Like him, she adopted a memory "Aufgabe." Like him, she had begun an analysis of the situation into its elements and was tentatively associating, in a more or less accidental and external fashion, one nonsense-word with a certain element or group of elements when the warning was given in the sixth sitting against external and irrelevant asscіations (see Appendix). And like S. she interpreted this as meaning that any association of a syllable with some one feature of the presentation was illicit. Her sole duty was hereafter felt to be to observe accurately, report fully, and not to speculate. This last task, she explained later, was by no means easy for her. Continually there came the desire to seek the underlying principle, but she always inhibited it. This is borne out by the protocols. A very striking characteristic of her procedure was her use of the two syllables as one name. It will be remembered that subject W. exhibited the same tendency, but abandoned it when she found that the syllables were used in varying combinations. J. does not thus give up the "name" idea. Each combination of syllables remains a particular name for a particular picture.

J., *c* XII, *Dut* (*Bef*). "*Bef Dut* visually appeared, then *Wej Dut*. No picture during reaction period. Afterward I saw pictures of both; of *Wej Dut* which is [drawn] with fine green stripes across it; then of *Bef Dut*, [also drawn] in the one square of which was the red butterfly. I realized my mistake made twice in reports of calling the last picture *Wej Dut* instead of *Bef Dut*, its true name."

This type of recall might in time have suggested, in a way that the subject could not inhibit, that *Dut* went with just the outline. Unfortunately, the operation of memory is not uniformly correct, and instances occur where *Dut* is said to go with some other shape. Yet by the end of the fourteenth sitting

some kind of system is really developing. Take, for example, the last protocol, where the reaction word was *Nud:*

"This brought up a visual image and almost immediately the syllables *Wej, Nud,* and *Jid.* I thought of the figure in brown [draws *Nud*] and then in blue, and wondered if I should ever be shown it in blue again."

Question: "When did the three syllables occur?"

Answer: "All came with the brown image."

Question: "Which seemed most intimately to mean your visual image?"

Answer: "Oh, *Nud,* then *Wej.*"[6]

From the fifteenth sitting on, associative abstraction becomes more and more effective. The shapes begin to be pretty correctly associated with their syllables, but the patterns are not yet names. Take, for instance, the subject's reaction to *Bef:*

XVI. "The picture named *Dut* appeared followed by the picture named *Yol.* [She draws both correctly with indications of a *Bef*-pattern]. In reaction period, I realized that both had in them this peculiar red figure and the same color of background."

Bef soon becomes associated with this pattern; but it should be noted that *Bef* is not thought of as a pattern but as a figure.

An excellent example of how far associative abstraction can carry one is seen in XVIII, where the reaction word was *Bef.*

"This syllable occurred to me as belonging to some picture having butterfly designs in it. It seemed to belong to *Nud* and *Yol* both."

At the end of the nineteenth sitting, the subject spontaneously offered the following remark:

"There is a tendency to associate pictures of one color or pattern, *e. g.,* all the pictures with lines every way in brown go together. Also the different pictures in blue with lines of two shades forming stripes. Both *Yol* and *Kuc* have had this brown pattern."

The experimenter determined to ascertain just how much the subject had learned. Accordingly the following questionnaire took place:

E. "What are *Yol* and *Kuc*?"

O. "*Yol* is the elephant and *Kuc* the picture with the cuts in the side." (Both right.)

E. "Can you name any others?"

O. "*Nud* is the tall picture with the rounded top." (Right.)

Questioned about the other figures, she replied that they seemed to change all the time. As remarked before, both *Kuc* and *Yol* had had this brown figure with lines.

E. "Do I understand you to mean that these are merely rather attributive of *Kuc* and *Yol*?"

The subject was puzzled and denied it. "I used to think that *Bef* was the name of the little red figure, but I don't think I can carry this idea through."

E. "What was the brown lines picture?"

O. "As to name?"

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[6] This answer must not be taken as proof of abstraction, as it is in accord with a characteristic set which somewhat hindered the subject's advancement, viz., her tendency to regard the shape as the really important thing, the color-pattern rather subsidiary. *Nud,* moreover, meant the whole picture, brown coloring and all.

E. "If you care to put it that way."

O. "Well, once it was *Jid Kuc* and today *Gej Laj*."

The subject similarly showed no ability to name the blue picture. In the course of the conversation she mentioned *Laj* and the vest-shaped figure.

E. "What about this figure?"

O. "Well, it used to be *Laj*, I thought, but lately there has been a change. *Laj* has been used elsewhere and the vest figure has another name." (This was not actually the case.)

E. "Can you name any other picture?"

O. "*Dut*." (Describes *Dut* correctly.) "We have had *Jid Dut*, *Wej Dut*, and *Bef Dut*; that's all I can think of. (Pause.) That is all of the pictures: elephant, cut, vest, this one and the *Nud* long one." (This last was a sort of thinking out loud.)

E. "Well, now you have five pictures and names of at least four, perhaps for five. What are the other syllables doing?"

O. "Just floating in air, I guess. You see the four syllables keep the name with their pictures (as I said, *Laj* seems lately to have been changed); but the other syllables change. Can it be that the other syllables change when the colors do? [This came to the subject obviously as a flash of inspiration.] Anyhow they are modifiers."

E. "Can you test your hypothesis?"

O. "Well, there's *Gej Yol* and *Bef Yol*." [Describes the latter correctly; for the former she describes *Wej Yol*, there having been for some time a consistent substitution of one of these for the other.] Then there's *Miz Yol*. That has the little red figure. No, that's *Bef*. Well, *Miz Yol* is just brown. That's all the *Yol's* I remember. There are probably more."

E. "Try another."

The subject tries various colors. *Bef* has always gone with the red figure.

E. "Well, try another figure."

O. "*Kuc*; *Miz Kuc* has the brown wavy lines. *Bef Kuc* has the red figure. *Jid Kuc* I have seen but have forgotten. *Miz Kuc* looks like *Miz Yol*. It really looks in about three-fourths of the cases as if the last syllable goes with the shape and the first with the appearance inside. I can't remember enough to be sure."

In the next sitting the presentation period was omitted and the syllables were presented for reaction as usual. In the second protocol, *Gej* being the reaction word, the subject described a certain visual image. The experimenter then inquired: "Well, what is *Gej*?" to which the reply was given: "*Gej* and *Laj* together make that blue picture. *Gej* appears with other syllables and hence can't be the name of the 'vest' pictures. *Laj* does not appear with any other picture save the 'vest'. When other syllables are with *Laj*, the color changes. *Gej* isn't anything by itself, unless the name of a particular color scheme. I don't think it has any particular group."

With regard to all of the other pattern figures, she declared that they were modifiers and just by themselves meant nothing. It was impossible to draw a *Jid* which was not a *Yol*, *Kuc*, *Dut* or *Laj*. *Bef* alone might possibly stand by itself as the figure which was within the figure. With this much of a start she would undoubtedly have reached a complete abstraction in a very short time, but the sittings already prolonged had to be broken off at this point.

Little additional light is thrown on the further development of the analytic process by the protocols of subject Mn. The analysis was fairly quickly and very definitely made. As has been said above, he also endeavored to reinstate the entire situation by the aid of any sort of mnemonic device. Some of these proved real aids to memory and all of them assisted in an analysis of the situation-complex. On the whole his reports are very detailed and his recall quite correct. In spite of a strong emphasis in the protocols on the visual image, it was evident that he remembered chiefly the verbal terms, either motor or auditory verbal or more probably mixed. He realized that the syllables had been changed around a good deal, and from the seventh sitting at least he realized that the pictures were compounds. But as his entire effort was to remember the presentation as seen with the given syllable that day, this fact is merely mentioned by him in passing.

Associative abstraction plays but a small part with this subject due to the episodic memory methods adopted. Hence, though the recall is fairly complete, there is little peculiar emphasis upon the constant concomitant. The subject was forced to break his sittings at the end of the fourteenth without having reached complete abstraction.

In summary, we find the subjects divided into two sharply differentiated groups according to their method of attack upon the experimental material. The first group had constantly in mind the problem of relevance, which was lacking to the consciousness of those in the second group. In the one case there was a definite intention to abstract, the purpose generally realized as such, to consider certain things only as relevant. In the other case, there was scarcely a trace of such intention.

The writer proposes that this intention be made the criterion of abstraction, and that only the former mode of attack be called abstraction. It is true that the term has been used in a more general sense for the process or processes by which one is more highly conscious of (or conscious only of) certain features of a complex situation. As thus used, it includes attention and what we have called (following Ach) associative abstraction. But this broader use of the term is not happy. For abstraction ceases to have, as immediate experience, any distinguishing characteristic. All of the part-processes described either in this study or in its predecessors are found in other contexts than abstraction. Abstraction in this broader sense would be distinguished from other processes only by the onlooker or by the reflective judgment of the observer. To use the psychologists' bug-a-boo, the distinction is "merely logical." If, however, we are allowed to restrict the term abstraction as proposed above,

a psychological criterion of abstraction as a process is given us in *the conscious intention to consider a given presentation in isolation from some or all of its relations.*

This intention may arise in the subject's consciousness in various ways: from instructions, as in the experiments of our predecessors in this field; from a knowledge of conditions and an acquiescence in them amounting to instructions, as with subject An.; from an analogy to previous experience, as with subjects W. and El. External conditions may favor in greater or less degree the arousal of such an intention; negative instructions can inhibit it to a very great degree; but with adults abstraction is such an habitual reaction-form of mind that negative instructions by themselves are not sufficient. The inhibition of abstraction where the material lends itself to abstraction (and most material does) implies not only very implicit acquiescence in instructions, but a consciousness busily engaged with other problems. With our subjects this intention was focal, but it seems likely that in most cases, after a short stay at the focus of consciousness, it recedes into the background.

The process of "true abstraction" as compared with "associative abstraction" is thus characterized by a difference of content, since in the latter the intention to abstract is lacking. The temporal course of the two is also different: true abstraction is rapid and sure; associative abstraction is in comparison slow and vacillating. Even in the end-result, where the two seem most alike, there is a marked difference. For in true abstraction, one may be distinctly conscious of the irrelevant, but conscious of it *as something rejected*; while in associative abstracting one is generally not conscious of the rejected material at all, or in lower degree. And this other content is not accompanied by a rejection-consciousness. Associative abstraction may appear as a cue leading up to true abstraction, while the reverse is never the case. These differences springing directly out of our experimental results leave no question, it seems to us, as to the inadvisability of considering under one heading two processes, psychologically so dissimilar.

This becomes even clearer when one considers the function of the two. Ach (1) has shown that associative abstraction is sufficient to establish general meanings.[7] A general meaning, however, is not the same thing as an abstract concept. Abstract concepts are called into existence in the service, immediately at least, of reflective thought. We form abstractions

[7]Ach says that associative abstraction arouses a "Bewusstheit" of the general meaning, but the conclusion is the same even if one reject such creatures as "Bewusstheiten."

because we desire to consider a certain presentation or quality either isolated from all its relations, or potentially in all possible relations.

On the other hand, a general meaning, as the functional psychologists have insisted, exists in the service of practical needs. For this, the closer link given in associative abstraction between the class name and the invariable concomitant of the varying situations to which the name is applied may suffice. Associative abstraction may present to us, as meaning, the general characteristics only of a certain term, and hence may serve to call forth a generalized form of action. But for reflective thought this is not enough. Even though perceived in a welter of concrete particulars, the given quality must be recognized as the only one that counts. This recognition it is which associative abstraction cannot yield. Abstraction in the fullest sense is a process limited to those who have reached the level of purposeful thought; it arises chiefly by means of reflection and in the service of reflective thought.

Summary

Abstraction begins either with analysis or with conceptual assimilation of the presentation. These may be described as partial *versus* total assimilation, for analysis is found to involve conceptualization of the resulting analyzed parts. That which chiefly determines whether the assimilation shall be total or partial seems to be the presence or absence in consciousness of appropriate mental categories, which permit the total assimilation of the presentation without too great violence either to the categories or to the presentation. Yet even where the subject has clearly such a category, a mental "set" for analysis (whatever this may really consist of) may cause partial assimilation.

The process of analysis is initiated by certain cues. In the first group of these, there is a preferential selection, through the operation of attention and memory, of certain parts of the presented material. In a second group, analysis is initiated because of the essentially analytic means of communication; hence these may fairly be called social cues to analysis.

The third group is characterized by the deliberate and reflective intention to analyze. Deliberate analysis may be itself initiated or at least suggested by the other cues (hence we have clearly something of a cross-division), but this form of analysis is marked off from the other cases by the apparent activity of the self. Analysis may be initiated by several, not infrequently by all, of these cues acting in unison. Particularly noteworthy, however, is the great influence of language habits, an influence which permeates our commerce with our environment at every turn and which, by its very nature, inclines us to analysis.

Conceptualization, or the assimilation to certain pre-formed mental categories, is likewise initiated by cues which permit of a certain grouping. In the first group of cues, assimilation is furthered by the fact that one's awareness of the presentation is accomplished through a modification or transformation of the primary sense-data. The presentation is apperceived in terms of other sense modalities, in feeling terms, in terms of use. This translation being only possible by virtue of the fact that both the presented sense-data and the "apperceiving mass" are aspects of a more general class, this class is thus brought into clear relief.

In the second group, the assimilation takes place through emphasis of some part of the primary data, either by blurring of part of the image or by selection of one part to represent the whole. In both cases, the representative element is one which unites the presented object to some relatively stable mental category. Representation by a verbal term is intermediate between the two groups. For although it is strictly speaking a transformation of the primary sense-data, the name is so closely connected with the things signified that it is felt to be a representative.

The cues of the third group presuppose not only definite categories, but that precisely this kind of presentation has previously been assimilated to them. In the first case, the name of the presentation as an individual or particular is inhibited; and, before it can be recalled, the general name comes to consciousness. In the other case, the class name, which itself seems to come unmediated, mediates between the presented situation and the mental category.

Analysis and assimilation develop into complete abstraction by slightly different steps, few of which could be studied under our experimental conditions. Where unfamiliarity made discrimination difficult, the subject is forced to seek out, deliberately or otherwise, the essential or differentiating aspect of the presentation. If this is the element to be abstracted, as is usually the case, such relative unfamiliarity is favorable to abstraction. Attentive emphasis to one aspect passes over easily into intentional neglect of everything else. Associative abstraction, the emphasizing in memory of the constant concomitant at the expense of the varying concomitants, helps very materially, but by itself does not lead to the abstraction of the essential element of the assimilated complex.

A consolidation of the analytic process precedes its change over into abstraction. In our experiments this change took place as the result of an analogy to past experience, an analogy which grew out of a fairly thorough knowledge of the grounds upon which it was based.

Associative abstraction may suffice for the development of a general meaning, but something more is required for an abstraction. The essential element in abstraction is *a definite, though perhaps marginal, intention to consider a certain quality in isolation from any of its particular relations.* Only a mind which is capable of reflective thought has need of such an intention. The "mental set" which includes this intention may be called the abstractive attitude. This attitude seems to be variously aroused: by instructions, by more or less unmediated analogy to past experience, by reflective thought about the situation, by certain intellectual needs. It is this which must be added not only to associative abstraction but also to conceptualization and analysis in order to convert them into full-fledged processes of abstraction. As a final conclusion, one ventures to call renewed attention to the importance of the study of certain problems without giving the subjects definite instructions, not only to avoid the subjects' prejudices but also to avoid profoundly altering by those very instructions the nature of the process ostensibly studied.

Appendix

Before the sixth sitting (El.'s seventh), Group *c*, "the subjects were warned," to quote a note made at the time, "not to use irrelevant associations. For example if 'Bac' should be given, they were not to liken it to 'Baccy' and thence to something in the picture like tobacco. They were even to repress any such tendencies." It is regrettable that the exact wording was not preserved; for this instruction was critical for S. and J., perhaps for P. and Mn. They somehow understood the experimenter to mean that they were not to endeavor to connect any syllable with some aspect of the picture (whereas he meant only to prohibit mediate and external or accidental associations), and it was this which led to the peculiar form of their abstraction. In view of the importance of this change, even a contemporary note is unsatisfactory. At the same time, the following additional instructions were given verbatim:

"I want to make clear certain distinctions. When you see the syllable, it acts as a stimulus to certain experiences. These are, at least in large measure, terminated by your reaction. Certainly all *voluntary* search for an association should terminate, although there may arise *spontaneously* certain relevant experiences. It is to see if such be the case that a short pause is enjoined. Next you are to *retrospect* upon this experience just passed. You are not concerned now—at least primarily—with your present experience but with a past experience. You are to describe, as accurately as in you lies, what took place in your consciousness during the reaction time. If you add what came afterwards—as is proper, if the experience is relevant—make clear that it did come later: '*As I write the above,* I am conscious that it is entirely wrong.' Again, I want first of all your actual experience rather than your interpretation of your experience. I do not bar this latter—indeed I am glad to have it, but I want you sharply to distinguish between fact and interpretation. Moreover, there are two kinds of interpretation. There is the interpretation which comes to you during the reaction period and there is that which comes as you write. The former is *very* important, the latter is often quite useful."

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A NOTE ON WUNDT'S DOCTRINE OF CREATIVE SYNTHESIS

By E. B. Titchener

It was on a country-walk in the spring of 1858, Wundt informs us, that the notion of creative synthesis, which was to play so large a part in his psychological system, first occurred to him as the answer to the riddle of visual space-perception.[1] In formal outline, his doctrine remains the same from the *Beiträge* of 1862 to the *Physiologische Psychologie* of 1910. We all know, however, that between the *Vorlesungen* and the *Physiologische Psychologie* Wundt had radically changed his views; and the story of this change, in the context of space-perception, throws so clear a light on his psychological development and his systematic procedure that I think it worth the telling.

The Period of Unconscious Inferences

For the first account of the doctrine of creative synthesis we turn to the concluding essay of the *Beiträge*. Here Wundt analyses the process of perception into three unconscious acts of inductive reasoning: colligation, synthesis or fusion, and analogy. We consider them in order.

(*a*) The uniform connection of sensory stimulation with reflex movement means the repeated pairing and therefore the intimate connection of objective with subjective (muscular) sensations. The mind takes cognisance of this paired relationship by an unconscious act of colligation, a form of induction by simple enumeration. Since *A* has, a thousand times over, been followed immediately by *a*, and *B* by *b*, the mind argues that *A* will in the future always be attended by *a*, and *B* by *b*; or, in general, that an objective sensation will always be attended by a subjective sensation. We are still far removed from perception; the combinations *Aa*, *Bb*, leave the component sensations *A*, *a*, *B*, *b*, just what they were; but we have, in the act of colligation, taken the first step toward perception.[2]

[1] *Erlebtes und Erkanntes*, 1920, 181 ff. Cf. Ueber psychische Causalität, etc., *Phil. Stud.*, X., 1894, 123.

[2] *Beiträge zur Theorie der Sinneswahrnehmung*, 1862, 442. There is here, I think, a confusion, at any rate a verbal confusion, between colligation as external mode of connection (the paired sensations are *ipso facto* colligated) and colligation as unconscious act of generalization (the paired sensations are the material of an enumerative inference). I have read the passage in accordance with what I take to be its general sense.

(*b*) The essential act is that of synthesis. The mind cannot, however, advance to synthesis of its own accord. Something must happen, something in the nature of an accident, which disrupts the colligation and starts the mind enquiring and comparing.

Suppose, for instance, that there are two luminous points, at fixed distances from the eye, and that they set up two distinct retinal sensations. These objective sensations *A*, *B* are combined with their corresponding muscular sensations *a*, *b*; we have verified our colligation. But suppose further that the points shift to new positions while the eye remains at rest. We now have two objective sensations, *A*, *B*, with no attendant *a*, *b*; our colligation is proved wrong. What happens?—I translate the somewhat cryptic sentences in which Wundt describes the synthetic act.[3]

"In this way the two distinct retinal sensations are apprehended for themselves alone, and yet at the same time are compared with the muscular sensations that correspond with them. The connection with muscular sensations that colligation has established is broken, since the difference between the retinal sensations conditioned upon the changed position of the luminous points is apprehended for itself alone, and yet at the same time the change of position is measured by the degrees of the corresponding muscular sensations. Here begins the activity of synthesis. In isolating the retinal sensations, but at the same time measuring them by the standard borrowed from the muscular sense, it moulds perception to the form, the constraining impulse to which lies in the sense-impressions,—to the spatial form. Synthesis in perception is thus a creative activity, since it constructs space; but this creative activity is in no way arbitrary; the sensory impressions and the external accidents that play their part in synthesis make it altogether necessary that space be reconstructed with absolute fidelity. The spatial form is the only form that can issue from the logical manipulation of the given elements of knowledge, and the spatial form is therefore the necessary product of this manipulation."

If I may be allowed to paraphrase these sentences in homely English, I think the course of the mind's argument would run somewhat as follows. The situation is, let me repeat, that two objective sensations *A* and *B* are given without their regular subjective accompaniments *a* and *b*. The mind then argues to itself, unconsciously, in this way:

"Here's an astonishing state of things,—a good *A* and a good *B* without a trace of *a* and *b*. How in the world can *a* and *b* have got away? Let me call them up, and see if anything has happened to them. Here's *a*,—it fits all right to *A*; here's *b*,—it fits all right to *B*. There's nothing the matter—curious, though, that *a* is so much stronger than *b*; I never noticed that before. Now I do think of it, I believe that all the local-qualities like *A* have strong *a*s, and all the local-qualities like *B* have weak *b*s. Yes, and I believe there's more than that; I believe that if the terms of the old familiar colligation were laid out I should find a real parallelism, graded series with graded series. But then there must be a reason, and I'm sure I don't—yes, but I do! I do see! I've got it! Why, if I only run *A* and *a* and *B* and *b* together, and all the rest in the same way, and just take every two

[3] *Ibid.*, 444.

in the lump, I can *place A* and *B*! I *am* placing them; *A* is there and *B* is *there*! Eureka! that's what that old colligation was for, only I hadn't sense to see it. What else *could* it have been for, graded local-quality on one side and graded strength of muscle-sensation on the other? The whole arrangement is luminous, once you know how to look at it. Now let me try the thing out elsewhere, and perhaps I'll find the rest of the world luminous too."

Great nonsense, of course. I submit only that it is more or less intelligible nonsense, that it reproduces the gist of Wundt's statement, and that it shows clearly the *locus* of the synthetic act. Not the nature of the associated elements, but the mind's unconscious logical *Verarbeitung* of those elements, is responsible for the emergence of the new type of experience. Left to themselves, under the external conditions of association, the elements would never have got beyond an habitual linkage that kept their character as experiences unchanged. The mind, as Wundt himself puts it later on, is thus like a logically-trained man of science, before whom the facts of colligation are laid with the request that he explain them.[4] It is true that, when synthesis has done its work, the resultant perception is exhibited to us as something natural and necessary, the only resultant that could have been expected. But just as there never was an unconscious mind whose operations did not reflect the conscious ingenuity of its inventor, so was there never a logically-trained man of science who did not, in the flashing moment of explanatory insight, take his explanation to be final and inevitable.

(*c*) The office of the third unconscious act, analogy, has been anticipated in the concluding sentence of my paraphrase. Analogy saves trouble and time: the work of synthesis, once done, need not be repeated. The act of analogy is therefore not essential, though without it we should find the business of perception laborious, and might have been satisfied to stop short of the refinements which we have actually achieved.[5]

The popular account in the *Vorlesungen* tells us that colligation is a generalising inference, which takes account only of externals; from the fact that a connection has taken place very often, we infer that it will always take place. Synthesis, on the other hand, searches for the ground of connection. It compares a number of colligations of the same sort, and traces the connective thread that runs through them; the connection then appears as necessary, and is therewith transformed into a fusion of the elements of knowledge. Synthesis thus furnishes something new, namely, the law of connection; it is the creative activity in the process of knowledge. The text then proceeds:

"The analysis which we have given [of space-perception] divides almost of itself into the two stages of colligation and synthesis. A luminous point appears in our field of vision; it arouses a retinal sensation of de-

[4]Ueber die Entstehung räumlicher Gesichtswahrnehmungen, *Philos. Monatshefte*, iii., 1869, 232; reprinted as Das Raumproblem in erkenntnistheoretischer Beleuchtung (1867)—a mistake for 1869—in *Kleine Schriften*, iii., 1921, 406 f.

[5]*Beiträge*, 444 f.

terminate local coloring; and with that is connected a movement-sensation, which in its intensity corresponds exactly with the distance of the stimulated point from the retinal centre. Such colligations are formed in large numbers, since every distinct retinal sensation is connected with a movement-sensation of a certain intensity. But when a number of colligations have taken shape, a comparison of them necessarily follows. Comparison shows that a gradation in the intensity of the movement-sensations corresponds with the gradation in the local coloring of the retinal sensations. In this way the retinal sensations are brought into that quantitative relation which corresponds with the relation of the movements and which—since the movement-sensation is something external to the visual sensation proper—can be apprehended only as an external, extensive relation. The bringing together of the different colligations, their comparison, and the inference based upon it,—all this is the work of synthesis; and the product of the synthesis, space-perception, is a wholly new creation over against the sensations it makes use of."

When once the act of synthesis has been performed, analogy steps in with a twofold function, anticipatory and time-saving.[6]

The Intermediate Period

It is needless to insist—for no one has made the point more clearly and decisively than Wundt himself—that this elaborate explanation explains nothing. It shows the confusions to which all common-sense psychology is liable, the confusions of logic with psychology, of form with content, of active principle with effect produced. The act of synthesis, in particular, makes flagrant appeal to a logical *deus ex machina*. There is an obscure plausibility as we approach the act, and again as we recede from it; but at the crucial moment we simply shut our eyes and open our mouth and see what applied logic will send us. An unfriendly critic might very well have said that the unconscious mind was hazarding a pure guess—or would have been, had not Wundt known beforehand the answer to the psychological question asked by the facts of colligation.

Wundt himself took the first step toward emancipation from logic in 1867, when he wrote, at the request of the editors of the *Vierteljahrsschrift für Psychiatrie*, a review of recent work in the field of physiological psychology. He still regards perception as a matter of unconscious inferences; but he deliberately drops the explanatory side of his theory, and seeks to develop it in descriptive terms, free of hypothetical entanglements. The sole task of psychology, he says, is to show—the possibility of spatial perception being presupposed—how the mind manages to bring its sensations, which are intensive magnitudes, into spatial order and arrangement; in other words, to exhibit the

[6] *Vorlesungen ueber die Menschen- und Thierseele*, i., 1863, 434 ff. I have not thought it necessary to refer to the deductive procedures of distinction and analysis: see p. 442. In *Beiträge* 439 f. we read that "the individual space-perception is the law which explains a determinate connection of sensations, and space at large is the general law which embraces all individual space-perceptions."

"instruments and activities" whereby a perception of space arises. The instruments are the two systems of local signs, the one a system of different qualities, the other a system of graded intensities. The activities consist in the interplay of these two systems. "A measure of the spatial distance between any two points can be obtained only by means of an intensively graded system of signs; but a system of qualitatively different signs is required in order that the metric relation obtained by means of the first system may be transferred to the qualitative impressions and in this transference be made permanent. The efficiency of either system thus necessarily depends upon the efficiency of the other." Beyond this point, Wundt says, psychology cannot go. The uniform connection of qualitative local signs and feelings of innervation "is" the perception of space. "And if my critics object that the question of the construction of space out of intensive sensations is, after all, no more answered by my theory than by others, I have nothing to reply. That question, if it is directed to psychology as empirical science, has been wrongly addressed."[7]

It looks, then, as if psychology were coming to its rights. No doubt, the perceptive theory which Wundt is championing presupposes "the familiar psychical processes of association and reproduction, of unconscious judgment and inference;"[8] but he has been able, nevertheless, to set it up free of logical scaffolding; and the reader who mistrusted the unconscious mind might even now, with sufficient psychological faith, have taken the theory and left the logic. It is, however, plain that Wundt is merely resting, for the moment, at a half-way house. The only plausibility that his theory can boast—and we have seen that, to our modern eyes, it is little enough—derives from the creative act of synthesis. Our supposed reader, for all his psychological good-will, must have been content to argue that, since intensive sensations are the sole possible basis of space-perception, any theory is plausible which assumes a strictly genetic form.[9] Wundt would hardly be satisfied to make so much virtue out of so bare a necessity. He must, therefore, unless that logical synthesis is to be restored, go further on his psychological way; he must seek a new plausibility, and must raise the question how it is at all possible that intensive sensations be translated into a spatial form. This question he takes up, two years

[7] Neuere Leistungen auf dem Gebiete der physiologischen Psychologie, *Vjs. f. Psychiatrie*, i., 1867, 33, 36, 40, 45, 46. Among the hypotheses dropped is that of the origination of eye-movements in reflexes (38).—Cf. *Philos. Monatshefte*, iii., 1869, 225; *Kleine Schriften*, iii., 1921, 399.

[8] *Vjs. f. Psychiatrie*, i., 1867, 45 f.

[9] Cf. Wundt's criticism of the empiristic theory: *Vjs.*, 39 f., 44. This criticism is renewed in *Philos. Monatshefte*, iii., 1869, 225 ff.; *Kleine Schriften*, iii., 1921, 399 ff.

later, in a detailed study of the genesis of visual space-perception.[10]

Space and our conscious contents have after all, Wundt reminds us, certain characters in common. They may both alike be subsumed to the concept of magnitude; they are both continua, magnitudes whose progression is continuous; and they are both continua of manifold dimensions. Here, however, the resemblance ceases. For the dimensions of a continuum may be variously interrelated. They may be disparate, which means that, though they belong to one and the same magnitude, they are otherwise wholly independent of one another and can never pass over into one another. They may be homologous, which means that they not only are themselves capable of continuous progression but also permit of continuous passage from one to another; colors, for example, represent a continuum of two homologous dimensions. And lastly they may be congruent, which means that they are not only homologous but also interchangeable; any given section of one dimension is congruent with an equal section of another. It is plain, now, that space is a manifold continuum of three congruent dimensions, and that our ideational content is a manifold continuum of three disparate dimensions—quality, intensity, time. Hence the question before us runs: How may a continuum of three congruent dimensions be derived from a continuum of three disparate dimensions?

The answer turns on the nature of these disparates. We can form a continuum of x congruent dimensions if we have given (*a*) a continuum of x homologous dimensions, to serve as material of measurement, and (*b*) a continuum of one (disparate) dimension, physiologically connected with it, to serve as measuring scale. By applying scale to material for all possible distances and in all possible directions we render congruent the homologous dimensions of the material and we read x dimensions into the originally one-dimensional scale. The procedure may be described either as the reduction of the heterogeneous material to measurements of a homogeneous scale, or as the multiplication of the homogeneous scale by means of a heterogeneous material. Its result must be the formation of a continuum of congruent dimensions.

Colors, as we have seen, represent a continuum of two homologous dimensions. The system of qualitative local signs is evidently a continuum of the same kind, and thus furnishes

[10]See Note 4. The question, after what has been said in the *Vjs.*, can hardly fall within the limits of empirical psychology. In his introductory paragraph Wundt proposes to discuss it "von einer allgemeineren psychologischen Grundlage aus;" but the new title of the *Kleine Schriften* makes it epistemological. The argument is utilized both in the *P. P.*, 1874, 685 f., and in the *Logik*, i., 1880, 459.

us with a material of measurement. In searching for a scale, we have to choose between the two one-dimensional continua—the two remaining disparate dimensions of the total ideational continuum, time and intensity. We can hardly hesitate. Every measurement by a time-scale would depend, first, upon the distance between the terminal points within the qualitative continuum which constituted the limits of the interval to be measured and, secondly, upon the velocity with which this distance had been traversed. The units of the time-scale would thus be variable and incomparable. So we are left with intensity, the intensity of movement-sensations or sensations of innervation; and here we find, in fact, both constancy of metric result when scale is laid upon material, and also that physiological connection between the two factors in measurement which the successful solution of our problem demands. A space of two congruent dimensions is thus assured.

What, then, of the third spatial dimension? We must, obviously, retain our intensive scale; for all three dimensions of space are congruent. But if logic and experiment are at one upon this point, so are they also at one as regards the original material of measurement, which can be nothing else than the third one-dimensional constituent of ideation, namely, time. Time-order in ideation, succession, plays a far larger part in the perception of depth than in the perception of surface, and the perception of depth itself shows always a certain indefiniteness, which points to a more or less variable and unreliable material. Presently, it is true, the work of time may be supplemented by that of other and more dependable materials, such as the stereoscopic differences between the images of the resting retinas. But unless time had been there to play its part as original material of measurement, we should hardly have attained to the perception of the third spatial dimension.

"Now, therefore, we can understand how it comes about that our ideation, which represents primarily a continuum of three disparate dimensions, is able to develop, in space, a continuum of three congruent dimensions." Wundt has answered his new question, and in answering it has once more made his theory plausible.[11]

The Psychological Period

We may still ask, however, whether this novel plausibility is more than logical. Does the essay of 1869 really do anything else than replace the unconscious induction of 1862 by a process of conscious deduction? And is the theory of visual space-perception, as a psychological theory, itself bettered by the change?

[11] *Philos. Monatshefte*, iii., 1869, 238 ff.; *Kleine Schriften*, iii., 1921, 413 ff.

We have, fortunately, Wundt's own reply to these objections in the doctrine of the *Physiologische Psychologie*. Five years are still to elapse before that work appears. When it comes, we see that Wundt's thought has profited both by the negative and by the positive results of the articles we have been considering; it has become through and through psychological. On the title-page of the *Beiträge* he could set the Leibnizian motto: *Nihil est in intellectu quod non prius fuerit in sensu—nisi intellectus ipse*; and the *intellectus ipse* shows as the unconscious mind, always ready to explain by inductive argument what otherwise must remain inexplicable. On the title-page of the *Physiologische Psychologie* he might (save for the dog-Latin of it) have set the motto: *Nihil est in intellectu quod non prius fuerit in sensu—nisi processus quidam penitus psychologicus*. The theory of space-perception is henceforth a psychological theory, wrought out in terms of immanent psychological process.[12]

We are all familiar with the details, and I need not spend time on them. The uniform teaching of the *Physiologische Psychologie* is that the "idea of space issues in every case from the connection of a qualitative manifold of peripheral sensations with the qualitatively uniform feelings of innervation, which by their intensive gradation are suited to serve as a general measure of magnitude," and that this issuance is psychologically conditioned.[13] The form of the statement changes, of course, but its substance remains. We have all learned it, and we are all prepared to reject it. Let us not forget, however, the tremendous array of experimental evidence that Wundt was able to set forth in favor of his hypothesis; let us not forget either the conceptual background against which he worked, and in particular the vague evolutionism of the late sixties and the seventies, which would make no bones of deriving space from the non-spatial. The synthetic theory was boldly planned and conscientiously wrought. It not only marked, scientifically and critically, a vast improvement on the older views, but for many

[12]As early as 1869 we find Wundt saying that "our consciousness does not originally possess the idea of space, but forms that idea by way of a *psychological process*" (italics mine): *Philos. Monatshefte*, 238; *Kleine Schriften*, iii., 413.

[13]The sentence quoted stands in 1874, 641; ii., 1880, 177 (sensations of innervation); ii., 1887, 207 (sensations of movement); ii., 1893, 233. In the first three editions Wundt's theory is genetic and synthetic; in the fourth it is a genetic theory of associative fusion. In the fifth and sixth editions the theory is a preempiristic and genetic theory of complex local signs, and the sentence changes to: "Only the conjunction of 'retinal image' and 'movement image' can produce the actual image of the object" (ii., 1902, 686; ii., 1910, 736). The identity of doctrine is affirmed in ii., 1910, 736, note 1.—The difference between the view of 1869 and that of 1874 is shown in a couple of sentences, 1874, 629 f.

years it also stood *facile princeps* among its contemporaries. And even now we, who have passed beyond it, cannot replace the Wundtian doctrine by anything as solid, as comprehensive, as unitary; the great single problem has split up into part-problems, and for these there is still a sad lack of phenomenological observation.[14]

I shall say no more, then, of the theory of creative synthesis. I wish rather, in conclusion, to call attention to certain corollaries to the preceding discussion,—points of unequal importance, but all illustrative of Wundt's personal 'psychology.'

(1) In the first place, we now seem to have a fairly clear picture of the genesis of the *Physiologische Psychologie*. We know the studies and researches upon which Wundt based his section on the physiological properties of the nervous system. We know that he had materials in the *Vorlesungen* for the section on sensations; and for the *Physiologische Psychologie* he could make use of Helmholtz' *Tonempfindungen* as well as of the *Optik*. We know, from what has been said in this paper, how seriously he had busied himself, in the interval between the two books, with the psychological problem of perception. We know, as I have elsewhere shown, that the doctrine of apperception shaped itself while the *Physiologische Psychologie* was actually preparing.[15] We know of his study of historical and current systems of psychology. We know, finally, of his physiologically motived interest in the reflexes, and of his social-psychological interest in expressive movements: in 1874 he had the use, too, of Darwin's *Expression of the Emotions*. All in all, therefore, we possess the materials for a detailed study of the sources and composition of Wundt's greatest book; and we may hope that some one of his pupils will presently undertake the task.

(2) It is natural to compare Wundt's doctrine of creative synthesis in perception with the 'mental chemistry' of the associationists.[16] There is, of course, no reference to mental chemistry in the *Beiträge* or the *Vorlesungen*. For one thing, unconscious logic was there making the requisite synthesis; chem-

[14]This breaking-up of the perceptive problem has meant also, of course, a shift of perspective or point of view. See esp. O. Külpe, *Grundriss d. Psych.*, 1893, 349.

[15]This JOURNAL, xxxii., 1921, 596 f.

[16]In *A History of the Association Psychology* (1921, 179, 264 f., 289 f., 293 f., etc.) H. C. Warren has emphasised the importance of this concept to associationism. I hope to return to the subject in a later Note.

istry was not needed.[17] For another thing, the space which results from the logical act is still, on the face of it, a natural and necessary resultant; nothing else could have been expected; whereas it is of the essence, *e. g.*, of J. S. Mill's mental chemistry that the unexpected happens; who should anticipate the issuance of white from the prismatic colors? We may accordingly find it the more significant that references to Mill occur in all six editions of the *Physiologische Psychologie.*[18] There could be no better proof, in a matter of detail, of Wundt's intention to psychologise his theory of perception.

(3) Lastly, I offer this paper as an illustration of one of Wundt's salient traits,—his profound respect for the continuity of his own thinking. As we pass from the *Vorlesungen* to the *Physiologische Psychologie,* we enter a new world. Wundt has discarded all the cumber of unconscious inference and can attack the preceptive problem psychologically. But he does not start afresh: that is the characteristic point of our whole story: he rather holds fast to the concept of creative synthesis, and seeks only to psychologise it. This temperamental trait, the tendency to retain his original conceptual tools long after they have done the work for which he forged them, runs through all his systematic work. It explains why there are two distinct theories of creative synthesis; it explains how he could pass as easily as he did from a sheerly motor sensation of innervation to "memory-images of movement-sensations;"[19] it explains why his doctrine of apperception represents not one but several theories.

[17]Wundt was familiar with the work of the British associationists, and also in all likelihood with the *Beytrag zur Physiologie der Sinne* of J.G. Steinbuch (1811). He tells us in 1869 (*Kleine Schriften,* iii., 407) that he deliberately turned his back upon associationism in order to make his experiment in logicism.

[18]See 1874, 639 f.; ii., 1880, 175 f.; ii , 1887, 205; ii., 1893, 231; ii., 1902 684; ii., 1910, 734. It is odd to find Wundt, in the last two editions, turning the tables on Mill by the remark that Mill's mental chemistry fails to lay due stress on the 'creative character of this psychical synthesis!'

[19]Cf., *e. g., Vorlesungen,* i., 1863, 221 f. (or *Vjs.,* i., 1867, 47) with Zur Lehre von den Gemüthsbewegungen, *Philos. Studien,* vi., 1891, 387 f.

SYNAESTHESIA AND MEANING

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1. Introduction

Although a vast amount of literature on synaesthesia has accumulated over a period of time as long as a century and a half, the real root of the problem seems never to have been unearthed,[1] and the difficulty has been that no investigator has attacked the problem intensively from an introspective point of view.

The investigation herein reported aims to describe the functioning of synaesthetic phenomena in a blind subject and to offer as check data the results from similar experimentation upon a second blind subject who is asynaesthetic. The data were obtained at different intervals of time from 1916-1921, but always under the same conditions and with carefully guarded instructions. Our synaesthetic subject, Thomas D. Cutsforth (*A*), is a graduate student in psychology and a well trained introspector. He lost his sight at the age of eleven. Our other blind subject (*B*), Leslie C. Blades, is likewise a well trained introspector, and at the time of experimentation was an advanced student in psychology. He lost his sight at the age of nine.

[1]See R. H. Wheeler, The Synaesthesia of a Blind Subject, *Univ. of Ore. Pubs.*, i, No. 5, 1920.

Owing to the fact that during part of the investigation observer *B* was not available, data from a third subject (*W*), the senior writer, have been used as check material.

The present study falls into two parts: (1) an analysis of the process of recognizing, and (2) a study of the development of meaning. The instructions to the reagents will serve as a description of method.

2. Group 1. Experiments on Recognition

Instructions to B.—"I shall present to you a Braille letter, punched in the middle of a rectangular piece of tag-board. You will find the tag-board located on the table directly in front of you and in a small wooden frame. I shall give you a ready signal, followed by 'now', whereupon you are to inspect the letter in normal fashion as if reading. The instant you have recognized the letter, stop and begin your introspection at once. Ready, now."

(*a*) *Typical Introspective Data*

1. *Observer B.* "(The letter was 'l'.) The *Aufgabe* was present to consciousness in terms of a focal perception of *E*'s voice, together with incipient tendencies for the fingers of my right hand to assume the position of investigating a point-letter and the vocal-motor-auditory: 'Wonder what it will be.' As I began to make the arm and finger movements across the tag-board from left to right consciousness was occupied with tactual sensations of smoothness and kinaesthetic sensations of keeping my finger in the proper position; these latter were localized principally about the wrist and elbow. During this procedure, however, my attention was centered tactually upon the tip of my second finger and I was conscious of a tactual 'set' or 'anticipation', a preparedness to receive an actual tactual impression of a point, part of which was also incipient strain localized in the finger and knuckle joints. Along with this 'set' were tensions about the brows and shoulders. Then I was tactually aware of touching the first point, the outstanding feature of which at the outset was a momentary consciousness of something other than smooth surface; this consciousness did not develop into a full-fledged awareness of a distinct point, but turned at once into an awareness of a solid line running at right angles to my finger movement. All of this occurred while the right side of my finger was in contact with the points and while the left-hand side of the finger was still resting upon smooth surface; in the fringe of consciousness there still lingered an awareness of this smooth surface. There then developed a very fleeting and vague tactual image of the letter 'l'; I noticed the difference between this tactual image and the perception which had thus far developed; the perception had as yet no definite ends either at the top or the bottom; it was merely the perception of a line; but the image contained a definite height; that is, the distinctive features of the perception were its straightness and direction while the distinctive feature of the image was its vertical length. I then found myself hesitating momentarily—a suspension of judgment—consisting merely of a slight tendency to inhibit arm and finger movement and of rising tensions in my throat and shoulders. I then moved my finger until the points fell beneath the middle of the fingertip; this movement was not straight to the right but was made in the form of a tiny arc; thereupon the letter clarified, first by a momentary standing out in focal tactual consciousness of the top point, the lower two points re-

maining as a bar or solid line. While the upper dot was thus being focalized I was momentarily conscious of its roundness and smallness. There then reappeared the tactual image of 'l', which entered consciousness very suddenly and developed at once to a high degree of clearness. I then found myself saying 'l' and began to relax, generally. During the entire process I was not conscious of familiarity as such. In fact the instant my tactual image of the 'l' appeared I began to relax."

2. *Observer B.* [Similar instructions, except that a New York Point letter was used.] "(The letter was New York Point 'f'.) As before, I was first aware of tactual and kinaesthetic sensations having to do with approaching the points from the left. The first point appeared as a localized, blunt pressure, with attention momentarily taking in the roundness and smallness of the point, while tapering off in consciousness was the smoothness of the paper against the left half of the ventral surface of my finger-tip. Then as my finger covered the letter as a whole I did not perceive the individual points; first there appeared a tactual bar or line with no definite beginning or ending; as this 'line'-consciousness lingered for an instant the three points became distinct, arranged in a straight line. Then there appeared a vague tactual image of a short line—its shortness and direction being the only definite features—in response to which I found myself relaxing and at the same time having the vocal-motor-auditory: 'f'."

Instructions: "I am about to present you with an object which you are to recognize tactual fashion. It will be located in the center of a rectangular piece of tag-board and the tag-board will be in a cardboard frame. Place your finger here (*E* guided *A*'s hand) opposite and to the left of the object. When I say 'ready' approach it slowly and as soon as you have recognized it begin to introspect."

3. *Observer A.* "As I laid my finger upon the tag-board and began to move across toward the right I was conscious of wondering what the object might be....., of the smoothness of the paper, and of kinaesthetic sensations in fingers, wrist and elbow. Then my attention was claimed, tactually, by a localized and rather sudden welling-up of a pressure sensation which did not develop into a consciousness of a Braille point but merely into the awareness of something blunt. The instant the above tactual impressions appeared I began to visualize the yellow of the tag-board; but when I came in contact with the first point my attention was absorbed with the change from smoothness to bluntness. Before this consciousness developed very far I became aware of two more blunt points localized adjacent to the first one; here attention centered momentarily upon the mid-position between the latter two points. There then at once appeared visual imagery of a jeweled pin, only the head of which stood out focally in consciousness; it was localized at my finger-tip and was followed very suddenly by incipient finger movement upward and to the left as if to ascertain if the pin would roll when I moved it. This visual image was fleeting and vague, involving merely a small area of yellow with two bright spots in the center. There then developed an awareness that the jewels might be set in the form of a cross, whereupon I found myself making very slight and incipient finger movements of exploring for the other jewels. In this process my finger came in contact with a point above those which I had already perceived; the instant this point appeared I found my attention grouping the three left-hand points spatially; the three-ness of the points gave way to a tactual line in which direction and length stood out as its prominent features. During this time the yellow and white of the visualized jeweled pin had been persisting. But now the tactual perception enlarged to take in the fourth point, on the right of the figure, and

at this instant the jeweled pin vanished, and suddenly taking its place was a yellowish-red blotch localized at my finger-tip; momentarily the tactual processes entirely receded from consciousness and I found my attention entirely absorbed with this patch of color, which was stable, clear and vivid. Then I found myself tending to relax; muscles loosened about the fingers, wrist, arm and shoulders, together with tendencies to take a long breath. This relaxation might have been interpreted as a feeling of familiarity, but I was not aware of it at the time as such. The appearance of the yellowish-red was my identification of the letter as 'k'. I had no vocal-motor imagery or other identifying imagery until after I knew that it was 'k'; the color informed me that the letter was 'k'."

4. *Observer A.* (Same instructions. *A* was aware that the object would be a Braille letter.) "The fore-period consisted of visual-tactual and visual-motor processes having to do with anticipating Braille letters. On beginning to move my hand to the right and slightly upward along the paper, as is my custom when reading point letters, I was first conscious of tactual-kinaesthetic-visual smoothness of the paper and of arm-movement. Upon reaching the first point I received a blunt tactual sensation together with visual imagery of the point raised up like a tiny knob from the surface of the tag-board and colored the yellow of tag-board. The second point was perceived and visualized in a similar fashion. But I had no sooner perceived the second dot than the two became spatially arranged in an oblique line slanting down and to the right. There followed a very sudden recognition of the letter as 'o', which consisted of a sudden change from the yellow-buff tag-board color in which I had been visualizing the points into a very light, faded potato-peeling-grey—an almost colorless, watery grey—tinged with a faint bluish darkness. But no sooner had this latter visual process developed than it was interrupted in its course by a tactual perception of another point above those which I had already detected. Before this latter tactual consciousness had grown into a definite tactual-visual awareness of a point I found myself in kinaesthetic fashion tending to make the bend formed by the three points; this was a fleeting and vague image but was localized in my fingers and wrist. Immediately following was the sudden appearance of a small bluish black area localized at my finger-tip, the visual image tending, as it developed, to assume the shape of the figure formed by the three points. Here my attention was centered upon the darkness, hue and shape of the visual process and the tactual elements entirely receded from consciousness. The color appeared suddenly and with no warning, the immediate antecedent of which was the motor image just described; it seemed as if the visual image instead of tactual processes were coming from my finger-tip; so sudden was the advent into consciousness of this visual image that it had developed before my finger had fairly covered the last point in the letter; immediately upon the advent of this visual image I relaxed. During the false recognition of the letter as 'o', tensions had increased; I had been momentarily conscious that the *Aufgabe* had not been fulfilled; this had consisted of facial, neck and shoulder tensions. Then (and now) I was not conscious of familiarity as such; the suddenness with which the color appeared, its persistence in focal consciousness with subsequent bodily relaxations, are all that I could say constituted familiarity. But my relaxation means to me a fulfillment of the task rather than an awareness of familiarity. The letter was 'b'; the bluish-black visual image meant 'b'."

5. *Observer A.* (Same instructions. The letter was 'q'.) "This process of recognizing was extremely rapid and involved only one movement of my finger. As before, I was at first conscious of the smoothness of the paper and of finger movement followed by the sharply localized blunt pressure of the lower point. I obtained the next two points as a bar, not two isolated points, with the focus of attention centered upon the mid-

space between them. This tactual-spatial perception was very fleeting and vague, and accompanied by a relatively much clearer visualization of the points in yellow-buff, raised upon the tag-board. With no intervening processes this visual imagery at once shifted to the reddish brown of 'f'; there followed a very attenuated perception of the upper two points of the figure, arranged as they came, in the form of a bar; this tactual-spatial perception lingered just long enough for me to 'catch' it and then shifted suddenly into the dark, pale, bottle-green of 'q'; the five points at no time became spatially arranged as a group either tactually or visually; the bluish-green of the 'q' appeared from above, rapidly covering the reddish-brown of the 'f', just as a curtain might fall and cover the one behind it. I had no sign of verbal imagery; the color of the 'q' covered a larger area on my finger-tip than did the color for 'f', the former being a larger letter. I was able to detect the manner in which the first color, meaning 'f', entered consciousness: it first appeared just above the upper joint at my finger tip and spread rapidly over the previously visualized points, covering the lower one last. In case of the 'q' the color appeared at the top, as did the 'f', first blotting out the upper edge of the colored 'f'-patch; it then spread downward until it formed a square area; then the left side of the square continued to 'grow' in a downward direction, forming a one-sided extension or appendage on the square. Thus the color, as it developed, shaped itself in the general form of the letter; it was only in terms of this shape of the visual image that I was conscious of the spatial arrangement of the points which go to make up the letter."

(*b*) *Summary of Introspective Data on Recognition*

Observer A. A's procedure in recognizing Braille letters may be summarized as follows. He first perceives the point or points with which he comes in contact. If the first point happens to be isolated, the tactual sensation momentarily lingers in consciousness; but if he comes in contact with two or more points simultaneously, he does not perceive these points as individuals, but finds that his attention is grouping them into a linear bar. For a brief instant this spatialization is tactual-visual, but tends at once to give way, entirely, to visual imagery of yellow points raised upon yellow tag-board. If the letter be a simple or small one, including not more than two or three points, there at once appears a colored area localized at his finger-tip. This area 'grows' into the shape of the letter, and the particular hue or brightness of this visual image constitutes either a tentative or final labelling of the letter. If, however, the letter is a large one, involving four or five points, this first color to develop may be a false recognition. The correction is made in terms of a new or second color which "drowns out," "covers," or "blots out" the preceding color. This last color to appear, the color which finally identifies the letter, is aroused by an antecedent consciousness the duration of which is so brief that it is reported merely as the awareness of "striking against something." The undeveloped consciousness of an additional point or bar of points in the figure serves to usher into focal attention the appropriate and final color. This undevel-

oped consciousness does not contain identifiable tactual elements. It is merely consciousness of "something."

Feelings of familiarity consist merely of the suddenness with which a color develops at the finger-tip, and the centering of attention upon the hue and shape of the colored area, with now and then a kinaesthetic process of anticipation or verification.

A's processes of recognizing, then, consist not essentially in the arousal of feelings of familiarity but in the *behavior* of colored visual imagery. If a color appears and runs its course with no interruption by the subsequent arousal of another color, the recognition is complete; if one color is superseded by another, the first constituted but a tentative or false recognition. In either case it is a color which has identified the letter in question.

(*c*) *Recognitions of A and B Compared*

B, like *A*, found himself arranging the points into bars or lines the instant they were detected tactual-motor fashion, and like *A* he was not aware of individual points as such unless they occupied an isolated position in the letter. In *B*'s case, as in *A*'s, the first spatial grouping of the points is vague, and does not include definite spatial limits; lines or bars are perceived as straight or as running in a certain direction; but at first their exact length or height is not perceived. In both reagents this vague tactual perception undergoes a process of clarification. *B*'s procedure here involves the appearance of a tactual image of the letter in which the bars or lines possess definite dimensions. In *A*'s case this clarification-process takes place in terms of visual imagery. Continued finger movement in both reagents results in prolonging and in further definitizing this spatial grouping of the points. In *B* the grouping is done in tactual-kinaesthetic terms; in *A* it is done in visual-kinaesthetic terms, the visual feature of the process beginning with images of the yellow-buff tag-board points spatially grouped as they are visualized, and ending in another colored visual image in which the individual points have lost their identity. This latter visual image identifies the letter by means of its hue and shape, principally by hue. This final grouping of the points in *B*'s case undergoes a similar dropping out of concrete and identifiable points; the spatial blend becomes perfect—the individual points lose their identity and appear as a grouped formation. This group is perceived as triangular, square, or what not, according to its form. But *B*'s mental content in this procedure is implicitly tactual, while *A*'s mental content is visual, the previous tactual processes receding or disappearing altogether.

To sum up *B*'s procedure in recognizing: there first appears a shift of attention from individual points to bars or lines; then

from bars or lines either to tactual imagery of a letter or to more definitely perceived spatial arrangements of these points. Here the points lose their individuality as separate bluntnesses and fuse into a spatialized blend; this latter process gives way to definite tactual imagery or to vocal-motor imagery of the letter. There is no visual imagery during the entire process.

Thus *B*'s processes of recognizing consist of the development of tactual and later of verbal imagery from tactual perceptions. *A*'s processes of recognizing consist of the development of visual imagery from tactual perceptions. The content which labels the letter in *B*'s case may be a tactual or a verbal image. In *A*'s case it is invariably a colored visual image of a certain hue, brightness or shape. These colors are identical with those which appear whenever *A* is thinking in terms of letters; they are the same as appear upon hearing the letters of the alphabet pronounced, and they are also the same as appear in his alphabet and number forms. Imagery of letters is invariably visual imagery of these colors and not tactual imagery.

The striking fact which is derived from a comparison of *A*'s procedure with *B*'s is the similarity in function in the two individuals but the marked difference in mental content. *A* recognizes letters by means of their synaesthetic visual associates, but the fact that *A* is synaesthetic does not render his processes of recognizing functionally different from *B*'s. Stage by stage the two individuals recognize in identical fashion. Both reagents must identify the object to be recognized; in either case the object must be labelled. *A*'s synaesthetic visual imagery is not an incidental and superfluous process in recognizing; there are no incidental or superfluous processes in *B*'s recognitions. *A*'s colored associates for letters identify or label those letters, as does *B*'s tactual or verbal imagery.

(*d*) *Significance of A's Synaesthetic Phenomena in the Process of Recognizing*

The temporal position of *A*'s synaesthetic visual images in processes of recognizing clearly points to but one interpretation, namely, that the visual associates are the essential components of the process and that they are integral parts of the development of meaning. The blurred tactual perception of points in the case of recognizing Braille letters, for example, means nothing to *A* except as a preliminary stage in the course of recognizing, for it must be definitized by visual imagery. Then, after the points have been perceived in their spatial arrangement through the aid of visual imagery, the object does not yet mean a certain letter rather than any other letter of the alphabet. This visualized grouping of points must undergo a change or be identified with the aid of some subsequent process. It hap-

pens to be a stereotyped colored visual image and hence a synaesthetic image which thus identifies a certain spatially arranged group of points as 'b,' or 'l,' or 'q,' or what not. A parallel procedure is to be found in *B*'s processes of recognizing; but the latter involve tactual and kinaesthetic contents in the place of *A*'s synaesthetic images. Where meaning develops in *B*'s case by means of rapid attention-shifts from tactual perception to tactual image or from tactual perception to verbal image, or from tactual perception direct to motor relaxation, it develops in *A*'s case by means of a rapid shift of attention from an undeveloped tactual perception to a visual grouping of points, and hence by way of a stereotyped visual synaesthetic image to motor response, or (in the more mechanized recognitions) directly from an undeveloped tactual perception through a synaesthetic visual image to motor response. In every instance, however, a motor response or relaxation will not label a letter; there must first appear a colored visual associate. There is no doubt, therefore, that the colored associates of letters *mean* those letters, in *A*'s case, and that without these colored associates the process of recognizing could not take place.

This fact gives us a clue to the functional significance of familiarity in processes of recognizing. If we compare *A*'s procedure with introspections obtained by Woods in her investigations of recognizing[2] we discover that *A*'s colored visual imagery functions as a substitute for the incipient organic and motor responses which her *O*s reported as feelings of familiarity. The shift from tactual to visual attention in *A*'s case means familiarity; colored visual associates function both as a general and as a specific label for the object recognized. We assume that a feeling of familiarity is but a species of development of meaning, and that in a general way it identifies the object to be recognized as "old" or as "belonging to past experience." Since in *A*'s case the color which appears in connection with a certain perception is always the same as the color which appeared with that perception in all previous experiences, the presence of the color itself in a subsequent experience *is* the familiarity of that experience. In other words, since the visual synaesthetic image is always stereotyped, it *is* the same experience which was had before. There can be no doubt about the identity or sameness of the experience. The invariable and stereotyped feature of the visual associate thus attenuates the process of "feeling familiar;" it provides implicit certainty in any subsequent recognition-process; it allows for no hesitation, wondering, or fluctuation of attention. Hence the relatively prolonged and laborious process of experiencing a feeling of familiarity is unnecessary

[2] This JOURNAL, 26, 1915, 313-387.

in *A*'s case; for an object or perception indefinitely labelled as familiar is by the same process labelled once and for all definitely and concretely. The perception is not only "old" or "familiar," but a definitely and finally identified perception at the same time.

When we ordinarily recognize as familiar an object, a face,or a name, we often have the experience of "knowing what the object is" or of "knowing the name of the person whose face is familiar," but we are unable to recall the appropriate name which will finally identify that object or person. *A* experiences a certain difficulty in recognizing which further demonstrates our point made in the previous paragraph and which stands out in contrast to the difficulty ordinarily experienced by an asynaesthetic person. *A* often has the difficulty of properly translating a colored visual associate into the appropriate name. He has already definitely labelled a person or object by means of his own color-language, but he has forgotten the name which translates that color into the English language. Thus, in teaching biology, he sometimes recognizes and as far as his own consciousness is concerned he has definitely and finally labelled a certain butterfly or crustacean. The colored visual image which stands for that species is present in his consciousness, but the technical name by which the species is generally known has escaped him. In such instances as these technical names, as such, are entirely superfluous to *A*'s processes of recognizing or of labelling. They mean to him only terms by which the identity of the species in question is made known to other people. We have come to use these technical names themselves as final contents which function in our own private processes of recognizing as well as contents which function in social communication. But not so for *A*, whose own private processes of recognizing are complete when the appropriate colored visual associate appears, regardless of the subsequent arousal of a technical name. We believe that this illustration shows further how synaesthetic phenomena not only serve as substitutes for other imaginal processes in acts of recognizing, but also function as substitutes for "feelings of familiarity." Synaesthetic phenomena function both as general and as specific labels for objects to be recognized.

We cannot understand how all this could take place unless synaesthetic phenomena are derived from, and are directly allied with, synaesthesia proper. When a person has synaesthesia, for example colored hearing, a certain blue means a flute tone just as much as the auditory quality itself, and probably more so. As far as meaning is concerned, that person sees the flute tone as much as if not more than he hears it. The color has come to function as an integral element in the process of perceiving. And so with the more prolonged and elaborate processes of perceiving which we call recognition.

A further comparative illustration will show how *A*'s processes of perceiving are not different functionally from those of asynaesthetic persons. When the senior writer hears a flute tone he finds that the focal standing-out of the mellow, woody, round-like quality, together with tendencies to visualize a flute or to say "flute," constitute the *meaning* of flute. It is the behavior of attention with respect to the auditory, visual and kinaesthetic qualities which are present in the act of perceiving which constitutes the development of meaning. And without tendencies to visualize or to say "flute" the tone would not be that of a flute any more than that of some other similarly sounding instrument. But let one sound a flute in *A*'s presence: the mental contents which appear are different, but they function as has just been described. *A* does not attend to the fluty qualities as such at all; in fact he hardly hears them. But something rises suddenly into focal consciousness to take the place of focalized auditory qualities, for no sooner is the flute sounded than a certain quality of blue arises to focal attention. So far *A*'s procedure corresponds exactly to the procedure of an asynaesthetic person. In the former, a visual quality has developed; in the latter, an ordinary quality has developed. Next, however, in *A*'s case, the hue or other qualitative feature of the visual image is recognized or identified. This particular hue or quality identifies the sound as coming from a flute. This procedure corresponds exactly to that of an asynaesthetic person, who has tended to visualize a flute or to say "flute," in that both persons have now by their final procedure recognized or labelled the flute tone. As long as *A*'s attention fails to take in the blue color in perceiving a flute, he does not know the sound of a flute from the roaring of a distant locomotive whistle. So long as a similarly functioning contextual image does not develop in the consciousness of an asynaesthetic person, the sound of a flute cannot be differentiated from any other sound. We conclude that in the very beginning of *A*'s mental life synaesthesia developed as an integral part of perceiving. His synaesthesia *is* the act of perceiving, itself.

A's synaesthetic images function in like manner in his processes of recognizing. While from the point of view of the asynaesthetic person *A*'s visual associates stand for something else and mean something else than visual images, we must not conclude that their functioning in consciousness is different from that of the asynaesthetic individual. In so concluding we forget that the process of deriving meaning even in perceiving and in recognizing demands the presence of some process other than the one recognized or identified. Certain contextual imagery is necessary, such as the visual or the vocal-motor mentioned above in connection with perceiving a flute tone. *A*'s synaesthetic images happen to constitute this contextual imagery.

3. Group 2. Auditory Method

The above experiments lead to the conclusion that synaesthesia is a phenomenon of meaning in *A*'s case. In order to determine whether our interpretation and findings were correct, a second series of experiments was performed on subject *A*, with *W* as check observer.

In this series of experiments various lists of nonsense-syllables were presented to the reagent in auditory fashion. Each list included one or more meaningful words having the same number of letters as the nonsense-syllables, and was so arranged as to make the process of introspecting upon the development of meaning as easy as possible. This was done by varying only one letter of the syllable each time, as for example: bih, bij, bik, bil (l); or fab, mab, sab, pab, lab (oratory); and the like. Thus *A*'s consciousness during the presentation of the series and up to the appearance of the meaningful word would not radically change and would be simple enough in content to make a very detailed introspection possible. The changes which would then appear, as soon as *A* became aware of a meaningful word, would stand out in contrast to the previous mental processes.

The instructions to *A* were as follows. "I am going to present to you a list of nonsense-syllables, auditory fashion, in which there will appear, sooner or later, a meaningful word. The instant you are aware of meaning respond by saying 'now'. I will then stop the presentations. You will be asked to give me a very detailed introspective description of the processes involved in the development of the meaningful process." The syllables were presented at 1 sec. intervals in order to prevent the arousal of associations and in order possibly to provide instances in which *E* might repeat a meaningful word without arousing a response on *A*'s part.

(*a*) *Introspective Data*

6. *Observer A.* Series: bih, bij, bil (l). Response at once to the word 'bil'. "As *E* was repeating the first two syllables I was at no time focally aware of the sound of his voice; each time, just as the sound commenced, I was aware only of 'something', non-focally; then I found that my attention was at once claimed by a dark, bluish, thick amorphous patch of color, about the size of one's hand; with this color I was aware, non-focally, of repeating the syllable in vocal-motor imagery; the development of processes following the presentation of the third syllable was very rapid. Just as *E* was saying the 'b' of 'bil (l)' there appeared the same blue patch as before, and as before I found myself vocalizing the syllable, but with the focus of attention centered upon the patch of color. In case of the preceding syllables the blue patch remained during the vocalization of the syllables, *i. e.*, the color did not change. But I no sooner found myself vocalizing the word 'bil (l)' than there appeared, extended off from the right side of the blue patch, an area of white, from the 'l' sound in 'bil (l)'; the color came in as if the blue patch grew outward toward the right, while the left side

of the patch retained its original blue; along with the appearance of the white I found my eye-movement tending toward the right with the growth of the visual image. No sooner had this extension of color appeared than I found myself responding in motor fashion; and as I was reacting I had faint visual imagery of a sheet of paper which was the beginning of a consciousness that the 'bill' meant to me a legislative bill; the immediate antecedent of my response was the extension of the blue patch; meaning appeared with this behavior of the visual image, and this meaning was subsequently made more concrete by the appearance of the visualized sheet of paper, which, in turn, was interpreted in terms of vocal-motor imagery, but after I had reacted. I forgot to mention that with the appearance of vocal-motor imagery of 'bil (l)' the blue part of the synaesthetic image increased slightly in size and became more saturated."

7. *Observer A.* Series: bop, bor, bov, boy. Response at once upon hearing the word 'boy'. "As before, the auditory perceptions of the first three syllables involved a shift of attention to visual patches, the color of which was the same blue as for the previous syllables, and which was determined by the 'b' sound in the syllables. As I perceived the 'b' of 'boy' there appeared the same blue patch; then as my attention lingered upon this visual image I found myself saying the word 'boy' in vocal-motor imagery, but only non-focally; here the qualities of the vocal-motor image are indistinct and vague, obscure and undefinitized; it would be impossible to describe its qualities because there are no distinguishable qualities present other than a general image of movement, localized in my throat. In exactly the same fashion as in the previous case, the blue patch then extended on the right, first into the light yellow of the 'o', and farther on into a brighter yellow of the 'y'; my attention was wholly absorbed in these color-changes, which seemed to develop rapidly of themselves. I then found myself responding."

8. *Observer A.* Series: cag, caj, caz, cat. "During this experiment I found that the color of the first two syllables was determined by the 'ca' sound of *E*'s voice. I set up for myself the subsidiary task of inhibiting my vocal-motor imagery in order to ascertain whether or not I was using it. As a result of this inhibition of vocal-motor imagery I was unable to perceive the 'cag'. The 'ca' sound aroused a smoky-blue white, but I was unable to tell whether or not it had any meaning. The color merely appeared and did not change. Just as *E* was repeating the second syllable I had vocal-motor imagery of the first syllable—the 'cag' which I had only imperfectly perceived before—whereupon I recognized the colors as colors for definite letters; my recognition consisted wholly of a rapid shift from vocal-motor to visual synaesthetic imagery. I had previously recognized that the colors for 'ca' stood for 'ca' by means of accompanying vocalization of the 'ca'-sound; this color had drowned out the color for the 'g'; in previous experiments I found either that the color for the last letter in the syllable was not entirely drowned out or that I vivified that color by vocalizing the last letter; when *E* said 'cat' I was already anticipating the smoky-white patch which stood for the 'ca'-sound; but no sooner was the word pronounced than I had vocal-motor imagery of the syllable together with focal visual attention centered upon an extension of the smoky-white patch toward the right into the reddish-brown of the 't'; I then found myself reacting."

9. *Observer A.* Series: vad, yad, zad, sad. "When *E* repeated the first syllable, I found my attention at once claimed by a patch of colors, the hue of which was determined by the letter 'v'; on hearing the second syllable this color was slightly changed by the difference in the sound of the first letter, 'y'; then I at once began to anticipate the appearance of the third syllable in terms of this same color; so that, just as the third syllable was repeated, my visual attention was already absorbed with this color;

but the instant the 'zad' was pronounced there appeared a conflict between the persisting yellowish-grey of the 'y' and a reddish-brown patch, which latter tended to appear with the auditory perception of the 'z' sound in 'zad'. The first stage of this conflict consisted of a 'shaking' or 'shivering' of the 'y' color; then the colors for both 'y' and 'z' began to smudge or mix together into a sort of 'emulsion' of color, in which spots and streaks of one color intermingled, spatially, with spots and streaks of the other color; then I found myself having vocal-motor imagery of 'zad', whereupon all trace of the yellowish-grey of the 'y' vanished and was replaced by a smooth patch or area of reddish-brown. This awareness of color-conflicts was accompanied by a developing motor attitude of dissatisfaction and unpleasantness, characterized by tendencies to frown, marked tensions in the throat, and tendencies to tighten about the chest and shoulders. But there then tended to appear the yellowish-grey patch of the 'y' accompanied by vocal-motor imagery of 'y'; this was but the beginning of a consciousness that the first letter of the syllables should begin with 'y'; I was trying to visualize all of the first letters of the syllables alike instead of the last letters; this reappearance of the color for the 'y' took place just to the left of the persisting reddish-brown of the 'z', and for a moment there was perceptible eye-strain of tending to look toward the right as my imaginal line of regard lingered in the direction of the 'z' color. By this time *E* had pronounced the syllable 'sad'; this happened just as my visual attention was beginning to shift for the last time from the reddish-brown of the 'z' to the yellowish-grey of the 'y'; the auditory perception of 'sad' was accompanied by a sudden appearance of a light yellow patch which at once superimposed itself on or 'slapped down' over the persisting greyer yellow of the 'y'; the next instant I found myself having vocal-motor imagery of 'sad'; and together with this verbal image the light yellow patch enlarged toward the right, changing into a dull greenish blue, indicating the 'd' sound of 'sad'; concomitantly with this shift or extension from the right-hand side of the yellow patch I was aware of a motor attitude of satisfaction, consisting of pleasantness, which was bound up with chest relaxations, of relaxations about the abdomen, throat and mouth. This response also served as an awareness that the task was over. During the entire process, however, my attention was focussed upon changing colors and brightnesses."

10. *Observer A.* Series: hov, hot, hom, hop, hok. The reagent did not react until *E* came to the syllable 'hok', when he responded at once. "Upon perceiving the first syllable there appeared a very definite and vivid chocolate-brown color representing the 'ho'-sound, so vivid that I found myself momentarily absorbed in gazing at the color as it persisted in the focus of my visual attention. Then, as I found myself having vocal-motor imagery of the syllable, meaning tended to develop. This consisted first of a tendency for the chocolate-brown color to extend on the right into a very light, yellowish white; then it seemed as if I should subsequently recognize the meaning, but I could not; this latter consciousness was a slight tendency to relax in the presence of the changing color. But the motor relaxation—about chest and face—had but just begun when it ceased to develop and I found my attention centered, visually, upon a persisting yellowish-white patch; I was gazing blankly at the extended colored patch. This gazing continued until the next syllable was pronounced. The brown of the 'ho'-sound then considerably brightened and became more saturated; my visual attention lingered on this color more focally than before, but still nothing happened; nothing new then happened until *E* pronounced the word 'hok'; up to this time I was merely having the synaesthetic imagery *plus* the verbal imagery of the syllables; upon hearing 'hok' I vocalized it as usual, but there at once developed on the right-hand edge of the chocolate-brown patch a reddish-brown, almost orange extension; I found myself responding; the word had meaning the minute

this change in the visual imagery took place. The response consisted of a general, diffused bodily tendency to relax, particularly about the throat and chest. This response seemed to me a recognition of the fact that the change in the visual image had meaning. I then said 'now'."

11. *Observer A*. Series: xap, wap, sap. "During the fore-period I was aware of increasing strains about the throat, chest and jaws. Upon perceiving the first syllable, the appropriate color appeared at once in the foreground of my visual field. Nothing new appeared in consciousness until *E* repeated the word 'sap'; at this juncture I was already repeating the synaesthetic image in anticipation of the coming syllable; as I vocalized this syllable there appeared to the left of the 'p'-color the light yellow of the 's'-sound. Together with this change in the visual imagery I found myself tending to relax, but this did not develop very far. Consciousness was claimed focally by tendencies to fixate my visual field more rigidly than before; I was moving my line of regard about the yellowish-white synaesthetic image of 'sap' which was still persisting; this was the beginning of a consciousness of wondering what 'sap' it was; then the colors in my visual field turned into a large green area, out from the bottom of which there developed a brownish form; this was the beginning of a consciousness that 'sap' referred to 'tree sap'; then a tree-trunk stood out, developing from the brownish form which had just appeared; and as my visual line of regard centered itself upon the tree-trunk I visualized beneath the bark a layer of white wood. This completed my consciousness that the 'sap' was 'tree sap'. During this time I was non-focally aware of greater and greater bodily tensions, located particularly in the chest and abdomen. These latter processes consisted of a tendency to inhibit the response until the meaning was complete. The meaning seemed to develop in the changing visual imagery, and my motor attitude seemed to constitute a recognition of the fact that meaning was developing."

12. *Observer W*. Series: qec, pav, muz, yix, log. (Owing to *W*'s tendency to anticipate meaning in series of syllables arranged as for observer *A*, a different type of series had to be presented him.) "First I was aware of tensions about the neck, in the throat and shoulders, and about the chest, having to do with a rigid bodily attitude of preparedness to react quickly as soon as a meaningful word might appear. As *E* (Mr. Cutsforth) read the syllables I found myself attending focally to each one in turn, tending at the same time to translate a momentary focal auditory perception of the syllables into visual imagery of the syllables printed in large black letters on a white background; immediately following each syllable my attention was claimed by the rapid fashion in which all auditory features dropped out of consciousness, and by a shift to consciousness of my bodily attitude which was just described; in the auditory perceptions the consonants tended to stand out far more prominently than the vowels; yet these sounds disappeared from consciousness almost as quickly as they appeared. When the word 'log' was given I found that my auditory attention developed to a higher state of vividness and more vigorously than in case of the previous syllables; the perception of the auditory qualities was more sudden; there seemed to be a different quality in the auditory perception itself, consisting of the dominance now of the vowel-sound instead of the consonant-sounds as before; while this auditory quality of the 'o' sound developed suddenly to a very high degree of clearness, I found myself already responding bodily. This bodily response consisted of an incipient tendency to pull my shoulders together, to bring my head forward, and to jerk slightly my entire right arm. While this motor reaction was going on, my attention was at first still centered upon the 'o' sound of 'log'. But no sooner had the 'o' sound developed to a maximal degree of clearness than I tended to visualize, dimly, in a background of white light, the word 'log'; this process did not develop very far, however; during

this time I was looking in the direction of *E*, and slightly to the right of my line of regard there appeared but the beginning stage of a visual image of a timber log, lying on its side. Merely the shape of one end of the log, faint suggestions of corrugations of bark, together with a dark brown color appeared with any distinctness at all. Accompanying this shift in visual imagery from the word 'log' to a visualized log the motor reaction which had already begun greatly increased in intensity and became a generalized motor 'set' in the direction of the visualized log. The entire reaction was so rapid and the motor processes so diffuse and widespread that I could not detect many of the kinaesthetic details; the more sharply localized tensions were in the throat and about the eyes; the diffused parts of the reaction seemed to be vaguely localized in chest and abdomen. (I think that if someone had asked me, at the time I was perceiving the word itself, whether or not it was meaningful I should have said 'yes', although at that time there was no process which seemed to tell me what that meaning was. But upon the appearance of the visualized log the meaning became definitized. This particular visual image was so fleeting and vague that I am surprised that it occupied the focus of attention. I was attending to it rather than to the motor background.) The motor background seemed to consist of an attitude of recognition which I assumed toward the visual image of the log; it seemed to consist, in other words, of a recognition of the fact that the processes had meaning."

(*b*) *Summary of Introspective Data on the Development of Meaning*

So far as our series of experiments is concerned, development of meaning consisted, in *A*'s case, (1) in the manner in which visual synaesthetic phenomena developed; and (2) in the arousal of a diffused motor and organic reaction which took place immediately following the development of the visual synaesthesia. The first stage has to do with the growth of meaning proper, and the second has to do with the reagent's recognition of the fact that meaning has developed or was beginning to develop.

In perceiving a nonsense-syllable, *A*'s attention shifts to a visual concomitant of the sound of the syllable even while *E* is pronouncing it. This visual associate is determined by the dominant or repeated sound in the series of syllables. As long as in the perceiving of these syllables no processes take place other than a vocal-motor image of the syllable, together with the visual concomitant, the reagent does not react; the syllable is meaningless. The verbal image appears with the aroused visual associate, and is sometimes repeated in order to clarify or prolong the visual associate itself, but the verbal process remains non-focal throughout. When a meaningful word is pronounced by *E*, *A*'s procedure of perceiving the word begins as do his perceptions of meaningless syllables; his attention at once shifts from auditory qualities to their visual associates. But from this point on his procedure is different; meaning begins to develop. The antecedent of this development of meaning consists of a non-focal verbal image of the word itself,

together with the persisting visual concomitant, which latter is the same for the verbal image as it was for the original non-focal auditory perception. Then the visual associate which is being attended-to focally extends, or grows in size, taking on additional coloration as it does so. These colors are the synaesthetic associates of the remaining letters in the meaningful syllable.

So far the development of meaning has passed through its first stage, but the process is not complete for the reason that as yet the meaning itself has not been recognized. The instructions were to react when meaning developed. Hence the reagent was disposed to recognize meaning itself before he reacted for the benefit of *E*. If, after these colors changed as just described, *A* did not find himself assuming a motor attitude, *i. e.*, responding bodily to the change, the process of meaning was halted in its course. Such an attitude included relaxations in the chest, throat, and sometimes abdomen, and organic disturbances which were interpreted to be pleasantness. Without such an attitude or without some further mental process *A* finds himself unable to interpret the change in the color. The change in the color means something, but what? Vocal-motor imagery will not come to *A*'s aid, for the vocal-motor imagery itself is non-focal and cannot be attended-to as such; moreover the change in the visual synaesthetic image which has already taken place has identified the verbal image so far as it can be identified. Thus, with no further mental processes other than a shift in the colors, *A* finds himself staring at them, blankly; the colors themselves are unfamiliar or meaningless until they, in turn, have been identified.

If, on the other hand, with this change or extension in the visual synaesthetic imagery, *A* finds himself reacting in organic-motor fashion as well, he responds to the syllable as meaningful.

So far in our analysis of the development of meaning we have traced its course through two stages—that of coming into existence and that of being recognized afterwards. But our development of meaning is yet incomplete. The meaning is still general. Sometimes *A* reacted when the meaning was still in this generalized form (introspections 7-10); he reacted before the concrete meaning had been defined by behavior of additional mental contents. Sometimes he went on and defined this meaning.

Thus, if there is in *A*'s behavior an implied *Aufgabe* to go on and define this meaning (see introspections 6 and 11) there takes place a third stage. A second change appears in his synaesthetic phenomena. The synaesthetic processes already present to consciousness give way to further visual imagery or to com-

bined verbal and visual imagery. These latter processes define the meaning of the word, specifically. For example, in one instance *A*'s visual attention shifted from synaesthetic imagery of the word 'bil (l)' to visual imagery of a white sheet of paper. This was *A*'s method of defining 'bill' as a legislative bill. Again, the yellowish-white synaesthetic image of 'sap' gave way to a rapidly developing visual image of a green tree, hence to a tree-trunk in which white wood was seen beneath the bark. This was *A*'s procedure in limiting or defining the general meaning of 'sap' which had already developed when the synaesthetic image of 'sap' appeared. During the development of this third stage in the growth of meaning the organic reaction, characteristic of the second stage, is prolonged and this reaction functions as a general motor background for the subsequent mental contents.

W's procedure is not different functionally from *A*'s, but with respect to mental content it is quite different. *W*'s attention is suddenly and focally claimed by the auditory qualities of the nonsense-syllables. But when a meaningful word is pronounceds, this auditory perception develops with greater vigor and to a higher degree of focality. This suddenness and ease with which auditory qualities stand out in consciousness corresponds to the sudden clarifying and extension of colors in *A*'s consciousness of meaning. In either case the meaning has not yet been recognized. The procedure of both reagents thus far constitutes an implicit recognition that the word is meaningful, but the meaning itself has not yet been recognized. If the development of meaning should stop here, *W* would have found that the word "seemed familiar" or was "about to turn into meaning" or "ought to have had meaning." Such an experience on *A*'s part may be found in introspection 10. From this point on the appearance of visual imagery in *W*'s case and the shift from visual synaesthetic imagery to further visual imagery in *A*'s case constitute final limitations or definitions of the meaning which has already tended to develop. A motor-organic reaction in either case constitutes a recognition of the meaning itself. The additional visual imagery (it may not always be visual in *W*'s case) is the stimulus which evokes a widespread motor attitude, intensifying the already existing attitude, and is also the content which defines the meaning of the word. The prolonged motor attitude, which was at first a recognition of general meaning, now becomes a recognition of defined or limited meaning.

Thus meaning develops as a dual process consisting (1) of shifting mental contents which determine the presence or absence of meaning and whether the meaning shall be general or specific—a stimulus function; and (2) of the development of a

motor attitude in the presence of these shifting contents which constitutes a recognition of this meaning—a response function. The contents function as stimuli and the motor attitudes as responses. If the first appear without the latter, meaning is not complete. The *O* is then conscious only that meaning began to develop but failed of recognition. Thus the full growth of meaning consists not only of the process-aspect of shifting mental contents, but also of motor responses in the presence of these process-aspects.

There exist the same temporal relations between the focal standing-out of auditory perceptions and the motor response of recognition in *W*'s case as exist between the appearance of a synaesthetic image and the motor response in *A*'s case. *W* testified that meaning began to develop when the auditory processes become highly focalized, and that it was his subsequent consciousness of a motor attitude, which seemed to constitute a recognition of this developing meaning, that enabled him to offer this testimony. *A* testified that meaning began to develop when his synaesthetic image "extended," and that it was his consciousness of a motor attitude, immediately afterwards, that enabled him to offer his testimony. Careful reviews of a mass of introspective data verify these interpretations. We believe, therefore, that synaesthetic phenomena and meaning are species of the same genus of mental functions. Synaesthesis is an integral part of every cognitive process in a synaesthetic reagent.

A synaesthetic phenomenon is but a type of behavior of attention; and this type of behavior, whenever and wherever it takes place, constitutes a process-aspect of mental contents which in turn constitutes meaning.

We do not propose to assume that the growth of meaning takes place in all *O*s and at all times just as we have described it; but we are confident that, so far as our own experimental method is concerned, and so far as our own synaesthetic reagent is concerned, mental contents function as they have been interpreted.

(*c*) *Significance of Synaesthetic Phenomena in the Development of Meaning*

Our results from this series of experiments confirm results from earlier series. (1) Synaesthetic phenomena function in differentiating meaningless from meaningful processes, and are thus cognitive phenomena as far as their function in mental life is concerned; (2) these synaesthetic phenomena are identical with their original prototypes, synaesthesis proper; (3) in the same fashion as visual associates stand for auditory, tactual-kinaesthetic or other non-visual processes, these visual

associates stand for meaning; and (4) the functional problem in synaesthesia and in synaesthetic phenomena is the same; this functional problem is identical with the problem of meaning.

4. Group 3. Tactual Method

In order to demonstrate the development of meaning under such conditions as would necessitate a slow growth, several words were stamped in American Braille and exposed to *A*, one at a time, but in tachistoscopic fashion. That is, each word was exposed suddenly and rapidly several times, before the individual letters grouped themselves into a meaningful word. The reagent was instructed to make rapid sweeping movements over the word as a whole, at 3 sec. intervals, until the word was recognized. After a practice-series was performed in order that *A* might learn the necessary finger technique, a regular series of experiments was presented. Since the following introspection is typical of all our results we include only one example.

(*a*) *Typical Introspective Datum*

13. *Observer A.* Word: good. "(I recognized the meaning of the word upon the fifth exposure.) As the tip of my fingers passed over the word, the first time, I perceived the letter 'd'. This perception developed as follows: at the outset I was aware only of indefinitely grouped blunt points; these points at once became arranged, spatially, in terms of visual imagery, and at the same time took on the poorly saturated bluish-grey of the 'd'; at this juncture the obscure tactual qualities, which had at first appeared, entirely vanished and the color of the letter persisted alone in consciousness as my awareness of the letter itself. The second time I inspected the word the color of the 'd' persisted in consciousness; I failed to add any letters to my consciousness of the word; there only appeared meaningless and confused jumbles of tactual impressions which, as fast as they appeared, shifted to visual, grey imagery—my synaesthetic imagery of the temperature of the paper. But during this second inspection I anticipated in terms of grey-blue color the 'd' at the end of the word and also in terms of hurried eye-movement toward the right as my finger was moving across the word; this grey-blue visual image was a small irregular area of color localised at the right end of a rectangular grey form, which latter represented the word as a whole. The third presentation resulted in perceiving the 'g'. My consciousness of the 'g' developed in the same fashion as did the 'd'; the very light greenish white color for 'g' persisting in its appropriate position with respect to the oblong block. The fourth inspection resulted in perceiving the second 'o', which appeared first as a meaningless and indefinitely grouped mass of blunt points; the pressure qualities at once shifted to visualized points, and then suddenly into the dark, smudgy black of the letter 'o'. The last time I inspected the letters my attention was being claimed by persisting visual imagery of the three which had been perceived; I was only non-focally aware of finger movement; just as my fingers touched the points between the letter 'g' and the second 'o' (the points which were to become the first 'o'), and before these points were given time to arrange themselves into the spatial grouping of a letter, there appeared very suddenly a visual synaesthetic image of a double 'o'; this latter process was built up by an extension which grew out from the left side of the already existing black smudge which represented the second 'o'; that is, this already existing smudge doubled in size, forming a bar instead of a

small patch of darkness. But no sooner had this 'oo' developed in terms of visual imagery than the colors for the single letters (which had up to this time been separated by small inter-spaces of grey background) suddenly merged into a continuously colored streak. In this merged visual image, containing three colors, my attention was not centered upon any one particular color, but upon the group of colors as a whole. Together with this merging of the visual imagery I found myself having the non-focal vocal-motor image: 'good'. When I discovered the first 'o' I noticed the beginning of a motor expectation, consisting of incipient forward movements of my shoulders and of increased throat tensions. (I interpreted this motor attitude as meaning anticipation of fulfilling the *Aufgabe* and also desire to find out the meaning of the word.) As the colors of the word were merging into a solid group I found myself relaxing bodily. I distinctly noticed that the colors began merging just antecedent to the appearance of the vocal-motor 'good', and continued beyond my awareness of this verbal process. I will now describe the merging more in detail. First the color for the letter 'd' slightly shifted its position toward the left until its edges met and fused with the right boundary of the black smudge of the 'oo'; then before this change in position had completed itself the colored patch representing 'g' shifted slightly to the right until its edges fused with the left boundary of the 'oo' smudge. As these edges fused or blended, the colors now representing the word as a whole imperceptibly 'ran into' one another, very much, I suppose, as the colors of a spectrum. I was aware of the shiftings of color before I attended to my developing motor response. The motor attitude itself seemed to mean anticipation and expectancy on the one hand, and a fulfillment of the task on the other. The merging of the colors meant to me a recognition of the word, and this merging was emphasized by the vocal-motor imagery."

(*b*) *Summary and Interpretation of Introspective Data on Tactual Presentations*

Two problems present themselves with reference to the results of this and the former series of experiments. One consists of the significance of verbal imagery in connection with *A*'s synaesthetic phenomena, and the other has to do with the significance of *A*'s motor responses in the development of meaning.

The temporal relationships between the appearance of verbal imagery and of synaesthetic visual imagery in this and the preceding series of experiments indicate that verbal processes contribute to the development of meaning. A synaesthetic image is aroused either by an auditory or a tactual stimulus; but before this synaesthetic image has run its course, *O* finds himself having verbal imagery of the syllable or of the word. Since the verbal process *is* the syllable or *is* the word, one would expect that ordinarily no further process would be necessary for the development of meaning. The verbal image ought to identify or to label the auditory or the tactual perception. In *A*'s case, however, the verbal image always remains non-focal. But invariably the presence of such an image is directly followed by a change in the synaesthetic image toward greater focality—the visual image becomes brighter, more saturated, more permanent. Hence the verbal image seems to

be the cue by which the dissociated synaesthetic image is definitized. Further evidence of this function of verbal imagery is found in instances in which a synaesthetic image persists, alone, after the original auditory or tactual stimulus has faded entirely from consciousness. In the absence of such a non-focal process as the persisting but vague auditory or tactual feature of the stimulus word, the persisting and now detached synaesthetic image *means* nothing. This fact suggests that not only is meaning the process-aspect of changing mental contents, but that the content toward which the shift is being made must begin to develop in the presence of the dwindling of the content from which the shift was made. And when a synaesthetic image lingers in consciousness beyond the duration of the stimulus-content which aroused it, it becomes meaningless the instant the non-focal stimulus-content entirely vanishes. Under these conditions *A*'s verbal imagery appears as a substitute for the original stimulus-content; this introduces a new process-aspect, a new shift of attention, now involving a verbal image as the content away from which attention shifts; and the persisting synaesthetic image is the content to which attention shifts. Thus a re-shifting of attention toward the synaesthetic content provides it with the lost meaning.

The question arises: does the verbal content provide meaning to the persistent synaesthetic image, or does the existing synaesthetic image now function to provide meaning to the verbal image, as it did to the original auditory or tactual stimulus? Since the synaesthetic image existed before the verbal image came in, we assume that the verbal process identified the visual (note, the visual, momentarily, had no meaning prior to the appearance of the verbal process); but the verbal process, in *A*'s consciousness, has no meaning until identified by a visual synaesthetic image; hence, upon the appearance of the verbal process, the persisting visual process which lasts longer than the verbal subsequently defines the verbal process itself. This accounts for the fact, perhaps, that the visual synaesthetic image becomes intensified or clarified upon the appearance of the verbal process. It not only was identified but it, in turn, identified the process which had just identified it. This interchangeableness of stimulus and response functions, or of cause and effect, is not inconsistent. Logically, causes and effects and stimuli and responses must be interchangeable to function at all.

As to the second problem—the significance of *A*'s bodily motor responses in the development of meaning—our data from the present series of experiments furnish us with important suggestions. A careful study of *W*'s introspections in contrast to *A*'s shows that the former reagent lays much more stress upon kinaesthetic processes in the development of meaning

than does *A*. We have explained that these kinaesthetic processes evidently functioned as contents of recognizing the meaning of a word or syllable as it began to develop. The meaning was the "object" recognized, and the motor response was the recognition of the "object." But *A* showed fewer motor tendencies than did *W*. Evidently, then, something aside from motor tendencies in *A*'s case sufficed in the recognition of meaning, once that meaning began to develop. We interpret this difference between *W* and *A* to mean that in the former reagent processes of recognizing meaning are more explicit or overt, while in the latter reagent these processes of recognizing are more implicit; that is, they are to be assumed in the behavior of his synaesthetic imagery. We have already seen how in *A*'s case synaesthetic imagery labels an antecedent mental content both in a general and in a specific manner, thus attenuating "feelings of familiarity." This fact in itself means that *A*'s recognitions of meaning tend to take place implicitly because of his synaesthetic phenomena.

It is evident, however, that as far as meaning is concerned colors and their behavior alone do not suffice when a given train of associations terminates in a synaesthetic image. To possess meaning, *A*'s synaesthetic colors must themselves be recognized, or they must function as if they were recognized. One procedure by which these colors are recognized when they occur in prolonged sequences is by a shift of attention from one color to another. The product of this shift defines the antecedent color, implicitly. But if a train of visual associations fails to lead to a further shift in visual imagery, the development or the course of meaning is halted. Here the reagent must resort either to verbal or to other kinaesthetic processes. The final color is then recognized by means of a motor attitude. Thus, as long as colors keep changing from one to another, meaning is present for the time being, and whether or not such colors shall suffice to produce meaning depends upon whether or not the behavior of colors fulfils either an implicit or an explicit *Aufgabe*. Thus, in our last experiment, colors sufficed not in themselves but because they united the letters of the word "good" into the word "good." This union of colors satisfied the *Aufgabe*. In introspection 13 the behavior of colors did not satisfy the *Aufgabe*, for it led neither to a further change in colors nor to a bodily relaxation. Hence the colors meant nothing. To return, then, to a comparison of *W* and *A*, *W* habitually fulfils *Aufgaben* by resorting to complex motor attitudes along with changing visual, auditory, and other imagery; *A* can fulfill the same tasks by juggling visual contents, and with less kinaesthesis. But the instant visual synaesthetic contents cease to flow, *A*'s motor responses come at once to the rescue.

We can conclude, therefore, that the behavior of synaesthetic phenomena in our synaesthetic reagent is an adequate substitute in focal consciousness for the motor responses which were more important in our check reagent. But our synaesthetic reagent must have motor responses constantly on tap in a case of emergency. A careful examination of his introspective data shows that such motor responses are constantly on tap as a dim and oftentimes unnoticed background. He attends to changes in synaesthetic phenomena as long as they run their course; but if these synaesthetic images fail to run their course, he becomes conscious at once of the failure of the motor background to run its course as well. *A*'s mental life is characterized by a synaesthetic tendency to 'see' everything. The motor background which develops with the growth of meaning, and which came to the front so many times in *W*'s introspections, is not noticed by *A* for the same reason that auditory or tactual processes are not noticed. Visual surrogates symbolize them all. So *A* is over-determined or predisposed to find meaning in his synaesthetic images rather than in motor adjustments, in the same fashion as he is over-determined or predisposed to "see" sounds rather than to "hear" them. But just as auditory qualities in his colored hearing determine the behavior of the visual associate, and operate as a necessary background, so in the development of meaning the motor attitude is a necessary background for the behavior of detached synaesthetic images.

It is because the reagent is attending to *visual* rather than to auditory qualities when he hears sounds that it seems as if he were "seeing" sounds rather than "hearing" them. It is because his attention is centered upon visual qualities when he calls up *auditory* imagery of a sound that makes it seem to the reagent that he has auditory imagery when in reality no auditory qualities are present. And because his attention is centered upon shifting visual contents as meaning develops, rather than centered upon motor contents, he finds meaning in the former rather than in the latter. In every instance the process attended-to is the one which the reagent interprets as the bearer of the meaning. In every instance the last process attended-to—the last to run its course—is interpreted to be the content of the process of recognizing the preceding content. Hence *A* finds meanings in motor attitudes only when visual accompaniments cease or when a motor response terminates a given series of experiences.

All of this is illustrated by introspection 13. While the asynaesthetic reagent would probably have interpreted his motor attitudes as concerned with the development of meaning, as did *W*, *A* interpreted his motor responses as having to do

with fulfilling the *Aufgabe;* they meant expectation or completion of the task. Had colors not dominated *A*'s consciousness, it is most likely that his bodily relaxation at the end of the experiment would have meant the core of his recognizing the word "good," and would have been a response to the vocal-motor image "good." As it was, however, the merging of the colors was the core of his recognition-process, and the accompanying motor attitude which did not claim his attention until afterward was interpreted as a fulfilment of the task, not as a reaction which had to do with recognizing the word "good." Since the recognition of the word "good" was the fulfilment of the task, recognizing and fulfilling a task are here identical. *W* would have chosen the first meaning of the two; *A* chose the second because he is synaesthetic, and the behavior of his synaesthetic imagery meant the process of recognizing. Hence the motor response meant something else. In *W*'s case the motor attitude would have meant both, on second thought.

5. Conclusions

The real cognitive function of synaesthetic phenomena now becomes apparent; for (1) the appearance of colors in the first place constitutes developing auditory or tactual perceptions on the one hand, and (2) the further behavior of these colors constitutes shifts from one meaning to another as (for example) trom letter-meanings to word-meanings; (3) the behavior of these colors acts also as a surrogate for motor responses in focal consciousness, as long as the motor phenomena are present as an unnoticed background; (4) synaesthetic phenomena behave in such fashion that they can mean the fulfilment of a task; (5) meanings fail to develop in the absence of the appropriate behavior of synaesthetic colors; (6) synaesthetic imagery constitutes the context for meaning; (7) synaesthetic images operate as a substitute for feelings of familiarity; and (8) synaesthetic images 'label' or 'interpret' the 'object,' making it meaningful.

It is significant to note that in no instance did meaning develop for any reagent until a motor attitude or visualized motor attitude attended other sensory or imaginal contents. This fact suspiciously points to the conclusion not only that kinaesthesis is an essential component of the consciousness of meaning, but also that a motor response is necessary for the development of meaning.

SERIES OF DIFFERENCE TONES OBTAINED FROM TUNABLE BARS[1]

By Paul Thomas Young

Several years ago we noticed that unusually clear and loud difference tones could be obtained by striking simultaneously two bars in the upper octave of a standard set of orchestra bells. Although difference tones may be produced throughout the entire range of the instrument, which is two and a half octaves, they are especially distinct in the region from e^4 to g^4. The top octave, c^4 to c^5, contains frequencies ranging approximately from 2000 vd. to 4000 vd.[2]

Bars make an admirable type of apparatus for group demonstrations since they are easy to manipulate, simple in construction, and further since they make it possible to produce series, musical sequences and clangs of difference tones. The resultant tones are often more easily apprehended than the generating tones themselves. Demonstrational series of difference tones, obtained from a standard set of orchestra bells, were readily heard by groups of 350 elementary students in the University of Illinois.

In the following account we shall describe (1) series of difference tones obtained from a standard set of orchestra bells, and (2) tunable bars arranged for experimental study and for the demonstration of difference tones.

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[1]From the Psychological Laboratory, University of Illinois.

[2]It is interesting to note that Ellis, translating Helmholtz, uses tones in this region for the demonstration of difference tones. He writes: "I have found that combinational tones can be made quite audible to a hundred people at once, by means of two flageolet fifes or whistles, blown as strongly as possible. I choose very close dissonant intervals because the great depth of the low tone is much more striking, being very far below anything that can be touched by the instrument itself. Thus g'''' being loudly sounded on one fife by an assistant, I give $f''''\sharp$, when a deep tone is instantly heard which, if the interval were pure, would be g, and is sufficiently near to g to be recognized as extremely deep. As a second experiment the g'''' being held as before, I give first $f''''\sharp$ and then e'''' in succession. If the intervals were pure the combinational tones would jump from g to c'', and in reality, the jump is very nearly the same and quite appreciable." Helmholtz, H. L. F., *On the Sensations of Tone*, etc., Ellis trans., 1895, 153.

I. Difference Tones Obtained from Orchestra Bells. Table I shows the approximate pitch of difference tones obtained by combining pairs of bars in the top octave, c^4 to c^5, of the instrument. The pitch of the difference tones has been estimated on the assumption that the intervals are just, while, as a fact, they are intervals of an equally tempered scale. This means that the actual pitches will in some cases be higher and in other cases lower than the values indicated in the table.

TABLE I*

	$c\sharp^4$	d^4	$d\sharp^4$	e^4	f^4	$f\sharp^4$	g^4	$g\sharp^4$	a^4	$a\sharp^4$	b^4	c^5
c^4	$c\sharp$	c^1	$g\sharp^1$	c^2	f^2	$g\sharp+^2$	c^2					
$c\sharp^4$		d	$c\sharp^1$	a^1	$c\sharp^2$	$f\sharp^2$	$a+^2$	$c\sharp^2$				
d^4			$d\sharp$	d^1	$a\sharp^1$	d^2	g^2	$a\sharp+^2$	d^2			
$d\sharp^4$				e	$d\sharp^1$	b^1	$d\sharp^2$	$g\sharp^2$	$b+^2$	$d\sharp^2$		
e^4					f	e^1	c^2	e^2	a^2	$c+^2$	e^2	
f^4						$f\sharp$	f^1	$c\sharp^2$	f^2	$a\sharp^2$	$c\sharp+^2$	f^2
$f\sharp^4$							g	$f\sharp^1$	d^2	$f\sharp^2$	b^2	$d+^2$
g^4								$g\sharp$	g^1	$d\sharp^2$	g^2	c^2
$g\sharp^4$									a	$g\sharp^1$	e^2	$g\sharp^2$
a^4										$a\sharp$	a^1	f^2
$a\sharp^4$											b	$a\sharp^1$
b^4												c^1

*Difference tones produced by minor and major sixths have been omitted from the table, since these intervals were found to generate simultaneous first and second order difference tones. This corresponds to the findings of Krueger, Meyer, and others (references at close of this paper). For purposes of preliminary demonstration it seemed best not to complicate matters through the introduction of higher order difference tones.

We might add that f^2 combined with $f\sharp^2$, and also $f\sharp^2$ combined with g^2, which are the lowest bars upon our instrument, yield unusually clear summation tones. The tone of the first combination can readily be heard as higher than that of the second.

Difference tones exaggerate the defects of equal temperament. Since the pitch of the difference tone equals the absolute vibration difference between the generators, a small change of one of the generators, say n vibrations, makes a greater relative change in the difference tone.[3]

[3]The interval c^4—$c\sharp^4$, for example, does not correspond to the just ratio 15/16 but to a ratio slightly short of this, 84/89. If the ratio were just, the difference tone would lie four octaves below the $c\sharp^4$ generato.r It is found to be flat. In general, the semitone, tone, minor third, and fifth are too short in an equally tempered scale: the major third, fourth, and tritone are too long. (Calculated, *e.g.* from data in Helmholtz, *op. cit.*, Appendix, 453-456.)

We list below some of the series of difference tones which are useful for demonstrational purposes.

(1) By keeping a constant interval between the generators —as a semitone, a tone, a minor third, a major third, a fourth, a tritone, or a fifth— and by varying the generators themselves up and down the register, musical scales and simple melodies can be produced in the difference tones. If, while playing a melody, one attempts to change the interval between the generators, the disturbances which are due to temperament are at once apparent; but so long as one works with a constant interval, the difference tones have the correct tempered ratios among themselves (provided the instrument be in tune).

Chromatic series of difference tones, produced by generators which remain in a constant ratio, are to be found along the diagonals of Table I. For example, the following series of generators gives a chromatic series of difference tones:

Generator 1	$c\sharp^4$	d^4	$d\sharp^4$	e^4	f^4	$f\sharp^4$	g^4	$g\sharp^4$	a^4	$a\sharp^4$	b^4	c^5
Generator 2	c^4	$c\sharp^4$	d^4	$d\sharp^4$	e^4	f^4	$f\sharp^4$	g^4	$g\sharp^4$	a^4	$a\sharp^4$	b^4

By running down the instrument in semitones the series of difference tones becomes constantly lower and fainter and is nearly inaudible in the region of c^3. The loudest difference tones are obtained near the region from e^4 to g^4. This region, according to Helmholtz,[4] contains tones which are reënforced by the natural resonance of the ear. Generating tones above this critical region do not produce as loud difference tones as those within the region or near it. It is a fact of considerable theoretical importance that the loudest difference tones are produced from generators which receive natural resonance from the ear. We hope that further observations will be made upon this point.

(2) A descending series of difference tones may be produced from an ascending series of generators, or *vice versa*. The condition underlying such a series is that the absolute vibration difference decrease (or increase) as the generators ascend (or descend). The following series produces descending difference tones from ascending generators or, when played in the reverse order, ascending difference tones from descending generators:

Generator 1	a^4	$a\sharp^4$	b^4	c^5
Generator 2	f^4	g^4	a^4	b^4

[4] Helmholtz, *op. cit.*, 116, 179.

(3) A constant upper generator combined with a descending lower generator gives an ascending series of difference tones; played in the reverse order, a descending series. Following is an example:

Generator 1	c^5	c^5	c^5	c^5	c^5	c^5	c^5
Generator 2	b^4	$a\sharp^4$	a^4	$g\sharp^4$	g^4	$f\sharp^4$	f^4

A constant lower generator combined with an ascending upper generator gives an ascending series of difference tones; played in the reverse order, a descending series. Following is an example:

Generator 1	$f\sharp^4$	g^4	$g\sharp^4$	a^4	$a\sharp^4$	b^4	c^5
Generator 2	f^4	f^4	f^4	f^4	f^4	f^4	f^4

Series of difference tones of approximately constant pitch (which would be of identical pitch were the intervals just) may be obtained from ascending or descending series of generators. Reference to Table I shows that the same difference tone is produced by the following combinations of generating tones:

Generator 1	f^4	a^4	c^5
Generator 2	c^4	f^4	a^4

(4) Leaps of approximately an octave (based, not upon Table I, but upon actual tests with equally tempered intervals) may be produced by the following sequences:

Generator 1	$f\sharp^4$	g^4	|	$g\sharp^4$	a^4	|	$a\sharp^4$	b^4
Generator 2	f^4	f^4	|	g^4	g^4	|	a^4	a^4

Tones approximately in the ratio 4:5:6 may be obtained from the following generators:

Generator 1	f^4	$f\sharp^4$	g^4	|	g^4	$g\sharp^4$	a^4	|	a^4	$a\sharp^4$	b^4
Generator 2	c^4	c^4	c^4	|	d^4	d^4	d^4	|	e^4	e^4	e^4

II. *Tunable Bars for Experimental Study, and for the Demonstration of Difference Tones.* In order to make an apparatus capable of delicate adjustment and accurate control, and in order to avoid the difficulties arising from the use of equally tempered intervals—difficulties which are inevitable with orchestra bells and which are magnified in the difference tones

—we have made use of the tunable bar, previously described.[5]

Round top steel bars were obtained[6] and slotted from one end to the nodal line, which is approximately .22 of the length of the bar from each end. In this slot we placed a bolt (1/16 inch diameter, ¾ inch length) which carries a lock-nut. The bolt may be moved along the slot and clamped at any point. This arrangement makes accurate tuning possible.

We found that, by striking a bar on the rounded edge, two vibratory components were produced and also their first differ-

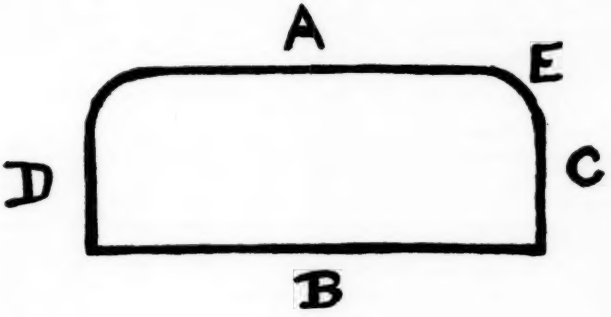

FIGURE I

ence tone. Figure I represents the cross-section of a bar in the center of its length. If the hammer strike at a point A, a tone is produced whose frequency varies directly as the thickness AB, and a blow at C produces a tone whose frequency

[5]Young, P. T., Tunable Bars, and Some Demonstrations with a Simple Bar and a Stethoscope. *Psychol. Bull.*, 1918, 15, 293 f.

Dr. C. R. Griffith has called our attention to the fact that the tone of vibrating bars is intensified by bringing a metal or cardboard funnel over the center. Although this funnel may act in part as a resonator, its chief function is probably to reduce the interference of the opposite-phase trains of sound waves which arise simultaneously from the center and ends of the bar. Intensification by means of a funnel is simpler than intensification with a stethoscope, the method which we have previously used. We might add that tunable bars have proved satisfactory for the study of beats in the elementary laboratory.

[6]The bars were purchased, at $1.00 a bar, from J. C. Deagan Co., Ravenswood and Berteau Aves., Chicago. The heavy metal hammers, necessary for striking the bars, cost 60 cents.

The bars have a cross-section of 1.1 x 2.6 cm. and, after tuning, the following lengths, in cm.:

Frequency of Bar	2600	2700	2800	3000	3200	3400	3600	3800
Length	14.1	13.5	13.4	13.0	12.6	12.3	11.9	11.6

varies directly as the thickness *CD*. Now if the blow of the hammer fall on the rounded edge *E*, two vibratory components are present and a difference tone is heard. By varying the cross-section of a bar it is possible to vary the ratio of these component tones, and hence to control the difference tone arising from them. But for our purposes, in order to avoid effects due to the lateral vibratory component, the bars have been mounted upside down, so that a flat surface is presented to the hammer.

The nine bars in our series are supported upon tightly stretched cords which pass through screw-eyes. The screw-eyes are arranged in two lines upon the base of a wooden frame and set at such distances apart that each bar is supported immediately beneath its nodal lines.

TABLE II

	2600	2700	2800	3000	3200	3400	3600	3800
Variable bar	0–	100–	200–	400–	600–	800–	1000–	1200–
2500 to 2600	100	200	300	500	700	900	1100	1300
2600		100	200	400	600	800	1000	1200
2700			100	300	500	700	900	1100
2800				200	400	600	800	1000
3000					200	400	600	800
3200						200	400	600
3400							200	400
3600								200

Table II shows all possible difference tones obtainable from our series of bars. The steps between bars of 100 and 200 vd. were selected because the laboratory possesses a set of forks (made by Spindler and Hoyer, Göttingen) which are tuned to the frequencies: 100, 200, 300, 400, 500, 600, 700, 800. For demonstrational purposes it is convenient to compare fork tones and difference tones.[7]

At the start we planned to tune the bars to the ratios 8:9:10:11:12:13:14:15:16. We soon found, however, that when the interval exceeded a fifth—when, for example, we worked with the minor or major sixth—two simultaneous difference tones were heard.[8] Consequently, for our purposes, it seemed best to

[7]We first tuned the 3200 bar to the double octave of the 800 fork and then the 2800 bar to the double octave of the 700 fork. Having established the frequencies of these two bars, and checked the difference tone with the 400 fork, we tuned the other bars entirely upon the basis of their difference tones. See Stumpf, C., Ueber die Bestimmung hoher Schwingungszahlen durch Differenztöne, *Ann. d. Physik u. Chemie* (Wiedermann's), N. F., 1899, LXVIII, 105-116; Appunn, A., Warum können Differenztöne nicht mit Sicherheit zur Bestimmung hoher Schwingungszahlen angewandt werden? *ibid.*, 1899, LXVII, 222–226.

[8]For discussions of the higher order difference tones see the papers by Krueger, Meyer, and others, references to which are appended.

limit our frequencies to those within the ratio of a fifth, 2:3 (we have actually stepped over this limit a bit). The fifth selected lies in the region where difference tones are loudest, *i.e.*, in the neighborhood of e^4 to g^4.

The following demonstrations may be readily made with the tunable bars.

(1) Difference tones of the same pitch may be produced from generators of different frequencies. If, for example, we strike any two adjacent bars, disregarding the variable and the 2700 bar, we hear a difference tone of 200 vd. Similarly difference tones of 400, 600, 800, and 1000 can be produced by several different combinations of bars (Table II). The 2700 bar makes it possible to obtain a difference tone of 100 vd. at two places, and also it gives the series: 100, 300, 500, 700, 900 and 1100.

(2) The lowest bar of the series is provided with a thumbnut and a load which is somewhat greater than that of the other bars, so that it may be varied continuously from 2600 vd. down to 2500. If combined with the 2600 bar, it yields a continuous series of difference tones from 0 to 100 vd. If the variable bar is combined successively with the 2600, 2700 and 2800 bars, a continuous series of difference tones from 0 to 300 vd. can be produced. This type of apparatus is admirable for studying the lower limit of difference tones and for other similar problems. It would be a comparatively simple matter to construct a series of tunable bars which would yield a continuous series of difference tones from 0 to 1200 vd. or above.

TABLE III

Ratios	Difference Tones	Generators			
1	50	2550	2600		
2	100	2600	2700		
3	150	2550	2700		
4	200	2600	2800		
5	250	2550	2800		
6	300	2700	3000		
1	100	2700	2800		
2	200	2800	3000		
3	300	2700	3000		
4	400	2800	3200		
5	500	2700	3200		
6	600	2800	3400		
1	200	2600	2800	2600	3800
2	400	2600	3000	2800	3800
3	600	2600	3200	3000	3800
4	800	2600	3400	3200	3800
5	1000	2600	3600	3400	3800
6	1200	2600	3800	3600	3800

(3) Series of difference tones, having the simple ratios 1:2:3:4:5:6 may be readily produced. Table III shows three such series, the first being obtained by setting the variable bar at 2550 vd. If we call a tone of 50 vd. *C*, then the following sequence may be produced by combining the tones shown in Table III:

C c g c′ e′ g′ c′′ e′′ g′′ c′′′ e′′′ g′′′

Here is a musical sequence extending through four and a half octaves produced by nine bars whose frequencies are all included within the interval of a minor sixth.

(4) Musical clangs, made up of difference tones, may be produced by striking simultaneously or in rapid succession bars which give only the small ratio numbers (1, 2, 3, 4, 5, 6). Table IV shows three such clangs. If one play successively these three clangs in the order 1, 2, 3, a series of musical chords will be heard, each one deeper in pitch and richer than the preceding. It should be remembered that to produce a musical clang of difference tones the generators themselves must stand in such simple numerical ratios as 13:14:15:16:17:18:19 or 26:27:28:30 or 51:52:54:56. We have calculated that with comparatively few bars it is possible to get a complete scale of difference tones in just temperament, and also from the same bars to produce difference tone clangs related as tonic to dominant, or as tonic to subdominant.

TABLE IV

Clang No. 1	Bars 2600 2800 3000 3200 3400 3600 3800
Difference tones:	200, 6 times; 400, 5 times; 600, 4 times; 800, 3 times; 1000, 2 times; 1200, 1 time.
Clang No. 2	Bars 2600 2700 2800 3000 3200
Difference tones:	100, 2 times; 200, 3 times; 300, 1 time; 400, 2 times; 500, 1 time; 600, 1 time.
Clang No. 3	Bars 2550 2600 2700 2800
Difference tones:	50, 1 time; 100, 2 times; 150, 1 time; 200, 1 time; 250 1 time.

If the bars are struck energetically, the clang has a piercing quality which may be almost painful, and which is localized in the ear. When the bars are played lightly, or with a moderate blow of the hammer, the musical chord is rich, full and true while the total clang is very bright, on account of the loudness and high pitch of the generators. Difference tone clangs are agreeable and, we believe, are not without musical value.

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Tonpsychologie, 1890, II, 243f.

N.B. The C. H. Stoelting Co., 3037-3047 Carroll Ave., Chicago, are manufacturing sets of bars of the sort described in the present paper for the demonstration and experimental study of difference tones. Also they are preparing differential bars for work with beats and the tonal *DL* (see foot-note 5). At the present time no price can be mentioned.

THE HYDROGEN ION CONCENTRATION OF THE MIXED SALIVA CONSIDERED AS AN INDEX OF FATIGUE AND OF EMOTIONAL EXCITATION, AND APPLIED TO A STUDY OF THE METABOLIC ETIOLOGY OF STAMMERING[1]

By Henry E. Starr

Psychology today is finding in reflex arcs and reaction patterns definite foundation-stones such as chemistry obtained in the concepts of atom and molecule. Behind the simple reflex, however, as well as behind the more complex performance, we find as prime determinants the amount of energy at the disposal of the individual and his degree of excitability. Energy and excitability, mutual interdependents to a considerable extent, condition both quality and quantity of performance, even when the latter appears to the unanalytical to be determined solely by motivation. And what is "motivation", that mysterious "mover" which the dualists call "soul", manifesting itself in hope and fear, desire and aversion, love and hate,—a labyrinthine complexus of interacting instincts, emotions, apperceptive residua, and bodily tone? May it not be considered as the resultant harmony or discord of the play, energetic or feeble, anabolic or catabolic, of metabolism upon anatomical structure?—harmony or "normality", if it blends with the environment; discord or "abnormality," if the pitch be too high or too low?

I have spoken of motivation as the resultant of the play of physiological processes. I do not insist upon that as a final mechanistic definition. For the purposes of this study I am quite willing to accept as a working hypothesis that the physiological processes are the result of psychical stimuli. That a misbehaving liver may spoil one's temper, or that a chronic ill-temper may affect the liver, may either or both be tritely true. What at this time I wish to call especial attention to is the fact that even motivation, that most psychical of psychological processes, is correlated with or parallels metabolism. Correlation of behavior with bodily tone is obvious in any performance. Efficiency, intellect, intelligence, all are being measured today by means of standardized tests, as a result of which the psychological examiner grades the performer on a relative scale, more or less accurately,—the degree of accuracy depending primarily upon the psychological diagnostic ability of the examiner. It is patent even here, however, that bodily tone, energy at the disposal of the performer, excitability, and general motivational attitude of the subject determine to some extent the amount of product he will turn out in a unit of time, his ability to put to use knowledge already acquired, his ability to solve what

[1]From the Psychological Laboratory and Clinic and the Robert Hare Chemical Laboratory of the Medical School, University of Pennsylvania.

is for him a new problem.[2] In every instance the physiological factor is evident. We may cling to the subterfuge of psychophysical parallelism, admit no interaction between the mental and the physical, regard them as such absolutely distinct categories that nothing of either can stand in a causal relation to anything in the other. But we must admit that the parallelism is frequently so close that between the lines there is scarce the width of Omar's false from true dividing hair.

Avoiding anything of a controversial nature, however, it is sufficient to note that the physiological may serve as an index of the psychological. This was pointed out by Bell in his "Anatomy and Philosophy of Expression," and the thesis was subsequently developed more scientifically by Darwin in his study of "Expression of the Emotions in Man and Animals." It is, in fact, the initial premise of the psychological examiner who observes a performance and interprets it in terms of thought, intellect, intelligence, etc. And if psychologists today are able thus to diagnose the mental conditions by observing gross bodily movements, what *finesse* they would gain by the employment of tests indicating quickly and accurately the metabolic status, degree of emotional stress, and energy at the disposal of the individual, irrespective of any attempts at malingering or excessive performance on the part of the subject, manifesting themselves in overt acts difficult of interpretation by a purely psychological procedure. Such indices, obviously, will have to be developed along the lines of the science which is employed for purposes of metabolic diagnosis, *i. e.*, of physiological chemistry. Physiology is the connecting link between psychology and chemistry. We need not go so far as to assert that psychology is a "refined physiology." We need simply to recognize the fact that the physiological parallels the psychological and is indicated by the chemistry of the individual.

In this connection Pawlow[3] merits special mention as having first reported the effect of purely psychical stimuli upon the digestive glands resulting in chemical differentiation of secretion. Cannon's work on the adrenals is a chemical study of the great emotives: pain, hunger, fear, and rage.[4] Crile's interesting and important attempt to portray man as an "adaptive mechanism"[5] would give to human behavior the foundation of a chemically activated kinetic system, consisting of brain, thyroid, adrenals, liver and muscles. Sajous,[6] Laignel-Lavastine,[7] and other investigators of the internal secretions have proved that the metabolism of the ductless glands is the chief etiological factor in many "mental" conditions.

Meanwhile, particularly along the lines of colorimetry and nephelometry, physiological chemistry has been rapidly developing an ever more delicate and accurate technique for the detection and determination of the products of metabolism. This is especially notable in the field of hydrogen ion determination, thanks largely to the work of Sørenson Palmer and Henderson, Clark and Lubs, and Cullen and Van Slyke. The time

[2]Definitions respectively of efficiency, intellect and intelligence, adapted from Witmer, Reference Book in Clinical Psychology and for Diagnostic Teaching, *Psychological Clinic*, May 15, 1919.

[3]Pawlow, J. P., The Work of the Digestive Glands. Trans. by W. H. Thompson. London, 1902.

[4]Cannon, W. B., Bodily Changes in Pain, Hunger, Fear and Rage. New York, 1915.

[5]Crile, G. W., Man—An Adaptive Mechanism. N. Y., 1916.

[6]Sajous, C. E. de M., The Internal Secretions and the Principles of Medicine. Phila., 1903.

[7]Laignel-Lavastine, M., The Internal Secretions and the Nervous System. New York and Washington, 1919.

is ripe for the application of the exact methods of chemical science to the problems of metabolism conditioning (or indicating) mental states. A psychological chemistry is due, from which may ultimately be developed a chemical psychology.

The material to be employed for chemical analysis, correlated with mental diagnosis, obtainable from a living human, may be the blood, urine, faeces, gastric juice, or saliva. As a means of investigating the metabolism of an individual the blood appears most admirable, in that it is itself virtually living tissue of the organism and carries the secretions, hormones, end-products of digestion, etc. Unfortunately, the popular fear of bleeding would no doubt militate against the usefulness of blood-tests as routine clinical methods of psychological diagnosis, and the fear reaction *per se* might so alter the blood as to render it of no diagnostic value with regard to the motivational or emotional *status quo*. The urine is accessible more readily and in greater quantity than is the blood. But it represents the waste-products taken from the blood by the kidneys and, in many cases, altered in transit. As such it is not a direct index of immediate metabolic condition such as manifests itself in more or less transient mental or psychical states. (Of course the general metabolic condition of the body may be frequently inferred from these waste-products.) The faeces, apart from the fact that they obviously would never become widely-employed clinical material, are contaminated by undigested food, and would furnish no index of material assimilated and thus affecting the economy, without an accurate preliminary analysis of the food ingested. Nor would they be of value as indices of transient emotional states, etc. To the gastric juice and stomach-contents objections may be raised similar to those advanced with respect to the faeces.

There remains the saliva. This fluid is constantly being secreted, swallowed, and passed through the physiological cycle. It may be readily collected for examination at all times and places. It may be regarded practically as transformed protoplasm of the secreting cell, with admixture of salts and other substances virtually dialyzed from the blood, and affected to a greater or lesser degree by the conditions obtaining in the oral cavity and by the constituents of the alveolar air. The glands of secretion have abundant neural connections with both the cranial and the sympathetic nervous systems. Thus of the three principal sets of salivary glands—sublingual, submaxillary and parotid—each one is innervated by both cranial and sympathetic nerves. The chorda tympani connects with the submaxillary and sublingual glands. The auriculo-temporal branch of the trifacial nerve supplies the parotid. As to the sympathetic fibres, to quote Fischer,[8] they "are derived in the

[8]Fischer, M. H., The Physiology of Alimentation. New York, 1907.

main from the second, third and fourth thoracic nerves, which, after passing into the sympathetic chain, ascend to the superior cervical ganglion, from which nerve fibres.....are given off that, after following the external carotid artery, are finally distributed to the various salivary glands." The amount and composition of the secretion of a given gland vary according to the nerve stimulated, as noted particularly by Heidenhain and by Langley. In his everyday experience the clinical psychologist observes the drooling of the idiot, and frequently the dry mouth of fear, the latter being especially exemplified by the well-known Chinese "ordeal of rice." Thus the saliva suggests itself as a possible index of metabolic conditions manifesting themselves in mental or emotional states.

That the salivary composition and reaction vary in health and disease has been reported by various investigators. Almost a century ago (1835) Donne noted that the saliva was acid to litmus in certain diseases, including encephalitis, whereas he regarded it as normally alkaline.[9] Today Kirk is the foremost protagonist of the diagnostic value of the saliva, especially with reference to metabolic factors in the etiology of dental caries,[10] and his kindly advice has been a distinct aid in the present research.

When, early in 1920, the Directors of the Psychological Laboratory and Clinic of this university asked the writer as to the feasibility of employing the salivary reaction as an adjunct in clinical psychological diagnosis, his first step was a survey of the biochemical literature bearing upon the problem.[11] He found that while many, and contradictory, findings had been reported as to the alkalinity and acidity of the mixed saliva under various conditions, much of the work had been of the crude litmus paper type. The more carefully conducted examinations had been made principally by titrational quantitative methods, in which field the work of Gies has been most intensive.[12] In titrational quantitative determinations the degree of acidity or alkalinity reported expresses conversely the quantity of alkali or acid required to be added to a definite quantity of the "unknown" (in this instance the saliva) in order to render the resultant solution neutral. The saliva, however, is an amphoteric liquid, *i. e.*, within certain limits it will act as an alkali to neutralize acids or as an acid to neutralize alkalis. Consequently titrational methods give no direct determination of the *status quo* of the intensity factor of the "acidity," which arises from the quantity of ionic hydrogen present in the solution. More recent chemical research in various biological fields, however, has resulted in the discovery that in the majority of instances the hydrogen ion concentration is a greater determinant of certain life phenomena than is titratable acidity. That is, the quantity of ionic hydrogen present in a given volume of the solution under examination is frequently a more important biological factor than is the quantity of hydrogen which may be replaced in the course of titration with an alkali.

It may not be out of place to note here that a hydrogen ion is an atom of hydrogen bearing a single positive electric charge; *i. e.*, it is a univalent anion. A hydroxyl ion (OH^-) is a chemical radical bearing a single negative

[9]Donne, A., *Arch. génér. de Med.*, May 1835.

[10]Kirk, E. C., *The Dental Review*, May 1903.

[11]For a review of the biochemical literature, see Starr, H. E., Biochemical Studies of Human Mixed Saliva. I.

[12]*Op cit.*

electric charge; *i. e.*, it is a univalent cation. When a substance is dissolved, it dissociates to a greater or lesser extent into anions and cations. Thus in the case of water (H_2O) itself there is a certain amount of dissociation, as expressed by the equation: $HOH \rightleftarrows H^+ + OH^-$. The lines of the equality sign are arrow-tipped in opposite directions to indicate that the reaction is reversible. The ratio of the product of the concentrations of the anions and cations to the concentrations of the undissociated molecular portion is a constant for a given salt in a given solvent at a given temperature. Thus, if

(A) = concentration of anion,
(C) = concentration of cation,
(AC) = concentration of undissociated molecules,
K = a constant,

then $\frac{(A) \times (C)}{(AC)} = K.$

In pure water, hydrogen furnishes the anion (H^+) and hydroxyl the cation (OH^-), while HOH is the formula of the undissociated molecule, hence

$$\frac{(H^+) \times (OH^-)}{(HOH)} = K.$$

Pure water, however, is so slightly dissociated [*i. e.*, (HOH) is so extremely great in proportion to $(H^+) \times (OH^-)$] that for all practical purposes we may discard the denominator, substitute another constant (k_w), and write our equation as:

$(H^+) \times (OH^-) = k_w$. Here (H^+) represents the quantity of ionic hydrogen and (OH^-) the quantity of hydroxyl ions. By electrometric determinations it has been found that for perfectly pure neutral water at 21° C. the value of k_w is 10^{-14}; and as in a neutral solution there must be an equal quantity of hydrogen ions and of hydroxyl ions, it follows that 1 liter of pure neutral water contains 10^{-7} grams of each kind of ions. Consequently if, at 21° C., a solution contains less than 10^{-7} gms. of H ions per liter, it contains more than 10^{-7} gms. of OH ions per liter, and is therefore "alkaline." Conversely, if it contains more than 10^{-7} gms. of H ions per liter, it must contain less than 10^{-7} gms. of OH ions per liter, and is therefore "acid." Or, perhaps more simply, if a solution contains more H^+ ions than OH^- ions, it is called "acid"; if it contains more OH ions than H ions, it is called "alkaline." But whether acid or alkaline it must contain some H ions, and consequently we may scale all solutions in terms of greater or lesser hydrogen ion concentration. As Sørenson pointed out, $\log_{10}\frac{1}{(H)}$ may be used to express a given hydrogen ion (H ion, or hydrion) concentration in lieu of (H^+). He suggested for this the symbol P_H^+. This Sørenson negative logarithmic notation, as it has been termed, is now quite widely adopted, the symbol having been simplified, however to pH. Thus a H ion concentration of 10^{-7} is written simply as pH 7.00. Or, for example, a solution of acetic acid, containing 6.0 grams of acetic acid per liter, has a H ion concentration of 1.36×10^{-3} which equals $10^{0.133-3}$ or $10^{-2.867}$, and which may be expressed as pH 2.867. Thus $pH = -\log_{10}(H^+)$. Because of the greater simplicity of the Sørenson notation the writer has employed it in the present research. It must be borne in mind throughout that the hydrogen ion concentration varies inversely as to direction with the pH; *i. e.*, a low pH indicates a high H ion concentration, and a high pH indicates a low H ion concentration. Consequently when the "salivary pH" is spoken of as increasing, the hydrogen ion concentration of the mixed saliva is decreasing, and conversely.

Prior to engaging in the present research, the writer found it necessary to make a series of "Biochemical Studies of Human Mixed Saliva" in the course of which was developed a technique for the colorimetric determination of the hydrogen ion concentration of the mixed saliva, or "salivary pH." The general procedure is to collect the saliva without the aid of a stimulus (as the chewing of inert substances was found to raise the salivary pH),[12] to make the determination immediately after ejection of the specimen without allowing it to stand or centrifuging it (as each of these measures was found to make for decreased salivary pH),[13] and to employ 1 cubic cm. of the saliva for a determination, which is made by adding dibromothymolsulphonephthalein or phenolsulphonephthalein to the saliva diluted with water of an H ion concentration of pH 6.6—6.7, and comparing the resultant virage with those obtained by similar treatment of standard solutions of known pH.[14]

It is obvious that the actual quantity of ionic hydrogen detected by the colorimetric determination of hydrogen ion concentration is quite small. Thus, there is required but 1 cubic cm. of saliva in the technique employed throughout this investigation. Consequently, if the hydrion concentration of the saliva is reported as 6.00, which means that one liter of the saliva contains 1/1,000,000 gram of ionic hydrogen, there has been actually determined in the one cubic cm. employed 1/1,000,000,000 gram of ionic hydrogen. Similarly, when the hydrogen ion concentration is reported as pH 7.00, it means that there has been determined 1/10,000,000,000 gram of ionic hydrogen in the 1 cubic cm. It may be of interest to note that a solution of pH 6.00 is indicated by a pale yellow color when phenolsulphonephthalein is used, and by a "grass green" when dibromothymolsulphonephthalein is employed; whereas a solution of pH 7.00 displays a distinctly red color with the former and a decided blue with the latter indicator. The color changes in the lower range are better indicated by the latter than by the former; for the higher ranges, the reverse is true.

Having thus an adequate technique, the next step was the determination of the hydrogen ion concentration of 610 specimens of human mixed saliva collected from 228 healthy normal subjects. The 610 specimens included 5 specimens each from 41 individuals; 4 specimens each from 6 individuals; 3 specimens each from 19 individuals; and 2 specimens each from 162 individuals. The range was found to be from pH 5.95 to pH 7.25, with 86.6% of the specimens within the limits of pH 6.55 to pH 7.00 inclusive. The mean was pH 6.78; the median, pH 6.80; and the mode pH 6.80 to pH 6.90 inclusive. The results of this investigation, in terms of relative frequency, are presented in Table 1, and also in Graphs 1 and 2. It was noted that in general, when the salivary pH was 6.60 or less, the individual appeared fatigued or deficient in the amount of energy at his disposal; when the salivary pH was about 7.00 the individual appeared to have an abundance of energy at his disposal.[15]

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[12] *Op. cit.*

[14] *Op. cit.*

[15] *Op. cit.*

Table 1. The Hydrogen Ion Concentration of the Mixed Saliva of Normal Healthy Individuals, in Terms of Relative Frequency.[16]

Hydrogen ion concentration of the mixed saliva	Relative frequency
pH	%
5.95	0.2
6.00	0.5
6.05	—
6.10	0.3
6.15	0.2
6.20	0.3
6.25	0.3
6.30	0.2
6.35	0.5
6.40	1.0
6.45	1.6
6.50	3.0
6.55	4.9
6.60	6.7
6.65	6.4
6.70	9.2
6.75	9.8
6.80	11.6
6.85	12.1
6.90	11.5
6.95	7.9
7.00	6.4
7.05	1.5
7.10	1.3
7.15	1.3
7.20	0.8
7.25	0.5

Following the determination of the normal physiological range of salivary hydrion concentration, experiments were made to ascertain whether or not a diurnal rhythm might be found.[17] Twenty-two salivary pH determinations were made at intervals during a day of inactivity and total abstinence from food, 22

[16]Adapted from Starr, Biochemical Studies of Human Mixed Saliva. The values of salivary pH reported are probably somewhat higher than the actual values obtaining in the oral cavity, inasmuch as in the method employed it was impossible to avoid a slight loss of CO_2 during the determinations with concomitant increase in pH of from 0.05 to 0.15 pH. This, of course, does not affect comparisons made between the values of pH found or the conclusions drawn therefrom.

[17]*Op. cit.*, II.

on a day of inactivity when a mixed diet was ingested, 16 on a day of normal activity and total abstinence from food, 14 on a day of normal activity when a mixed diet was ingested. A tendency toward a rhythm was noted; but the most marked and constant finding was a steady decrease in salivary pH from about 2.00 P. M. until the ingestion of dinner at 6.00 P. M. This result tended to confirm a tentative conclusion drawn during the preliminary investigation of 228 subjects, *viz.*, that the hydrion concentration of the mixed saliva increased when the individual was fatigued or lacked energy. Accordingly a series of 88 determinations[17] of salivary pH were made on 7 individuals during days of normal activity and mixed diet. The findings pointed practically invariably to a steady decrease in salivary pH during the afternoon, *i. e.*, toward the close of the working day when the individual's energy was ebbing and the products of fatigue, the principal of which is carbon dioxide, were accumulating in his tissues and blood.

In the course of the latter investigation, however, it was noted on several occasions that when a subject was emotionally excited his salivary pH increased regardless of the time of day. Thus subject I.G. at 3.00 P. M. had a salivary pH of 6.70; following some fairly strenuous exertion in the pursuit of his work, his salivary pH dropped by 4.00 P. M. to 6.60. At 5.00 P. M., just after the extinguishment of a slight fire at which he had been present, his salivary pH had increased to 7.20. By 5.30 P. M. it had subsided to 6.90, by 6.00 P. M. to 6.70, and by 6.30 P. M. to 6.60. Similarly M. S., having shown a salivary pH of 6.95 at 2.30 P. M., and a decrease to 6.80 at 3.30 P. M., having been angered about 4.15 P. M. by an individual against whom he dared not display his anger, showed at 4.30 P. M. a salivary pH of 7.25, which, as he grew calmer, subsided by 5.00 P. M. to 6.85 and at 5.30 P. M. had dropped to 6.65. Subsequent to these determinations subject I.F.T. one morning became quite angry. His salivary pH had just been found to be 6.75 at 9.00 A. M. At 9.15, when storming about quite angrily, his salivary pH was again determined, and found to have increased to 6.95. After he realized that he had misunderstood certain matters and that there was no real cause for anger, his salivary pH dropped by 9.32 A. M. to 6.80.

As a "check" on the preceding findings, the following experiment was performed. At 10.08 A. M. a 2 cubic cm. specimen of mixed saliva was collected from G.X.T., an adult male subject, known by the experimenter to be somewhat excitable. The pH of the specimen was 6.90. At 10.13 A. M. the subject was given misinformation calculated to anger him. It resulted as anticipated. At 10.28 A. M., at the height of his rage, he was commanded to "spit" which he did unthinkingly and with ve-

hemence. The pH of this specimen was 7.40. Unfortunately, the explanation of the operator, that the whole affair was staged as an experiment, did not result in any immediate calmness on the part of the subject. He left the laboratory in a rage, but returned about 1.00 P. M., when his salivary pH was found to be only 6.75. The results of the experiments upon normal individuals when laboring under emotional excitement [18] will be found tabulated in Table 2.

Table 2. The Increase in Hydrogen Ion Concentration of the Mixed Saliva Concomitant with Emotional Stress, in Normal and Healthy Subjects

Subject	Prior to Excitement Hydrogen ion concentration of the mixed saliva		During Excitement Hydrogen ion concentration of the mixed saliva		After Excitement had subsided Hydrogen ion concentration of the mixed saliva	
	Time	pH	Time	pH	Time	pH
IG	4.00 P. M.	6.60	5.00 P. M.	7.20	6.00 P. M.	6.70
MS	3.30 P. M.	6.80	4.30 P. M.	7.25	5.30 P. M.	6.65
IFT	9.00 A. M.	6.75	9.15 A. M.	6.95	9.32 A. M.	6.80
GXT	10.08 A. M.	6.90	10.28 A. M.	7.40	1.00 P. M.	6.75

Table 2 shows that under emotional stress four healthy normal individuals, whose average initial salivary pH was 6.75, displayed a decrease in hydrion concentration of the mixed saliva resulting in an average salivary pH of 7.20 which dropped, after they became calm, to an average of 6.73. This may not at first sight appear to be a very great change numerically; but it must be remembered that pH is the negative log to the base 10 of the actual hydrogen ion concentration. The *relative* increase is thus seen to be very great.

The writer next turned his attention to the chemical cause of the hydrogen ion concentration of the mixed saliva, with the result that he has found it to be due primarily to carbon dioxide.[19] This finding at once suggested the carbon dioxide content of the alveolar air, and therefore of the venous blood, as of etiological import. Accordingly 34 determinations of salivary pH in the usual manner, and simultaneous determinations of the carbon dioxide content of the alveolar by means of the Fridericia method,[20] were made on seven individuals, with the result that a definite correlation was found to exist between the salivary pH and the carbon dioxide content of the alveolar air,—the greater the former, the less the latter; *i. e.*, in every

[18] Compare with *op. cit.*

[19] In more correct chemical terminology it is due to the ratio $\frac{H_2CO_3}{BHCO_3}$ in which B represents a univalent base, according to the terminology of Van Slyke, and is to be so understood throughout. Cf. *op. cit.*, I.

[20] For detailed explanation of the Fridericia method for the determination of the carbon dioxide content and tension of the alveolar air, see Hawk, P. B., Practical Physiological Chemistry. 7th ed., Phila.

instance the H ion concentration of the mixed saliva was found to vary directly with the carbon dioxide content of the alveolar air.[21]

The correlation between the carbon dioxide content of the alveolar air and that of the saliva, the latter manifesting itself in hydrion concentration, suggested that a thorough ventilation of the lungs might result in decreased hydrion concentration of the saliva, especially inasmuch as Van Slyke[22] has found that the carbon dioxide of the blood may be "blown off" by voluntary deep breathing. Accordingly, the salivary pH of ten subjects was determined; and they were then placed out-of-doors and required to breathe "deeply and vigorously" for 10 min., when their salivary pH was again determined in the usual manner. It was found that in every instance the pH had, at least temporarily, decreased, indicating a decrease in the hydrion concentration of the mixed saliva.

The intimate association found in the course of these investigations between the hydrogen ion concentration and carbon dioxide content of the mixed saliva and the carbon dioxide of the alveolar air, in relation to concomitant states of fatigue and emotional excitement, leads to innumerable problems of relationship between breathing habits, mental and physical states, and all the ramifying sequelae of the hydrogen ion concentration of bodily fluids, respiration, carbon dioxide content of the blood, the functioning of the adrenals, and so on well nigh *ad infinitum*.

These biochemical and psychochemical findings were discussed with Dr. E. B. Twitmyer, Professor of Psychology and Director of the Clinic for Speech Defects of this University. Dr. Twitmyer has noted for many years that a large number of stammerers have very little chest expansion and may be denominated as "sub-breathers." Some—comparatively few—do not show this defect in the regular clinical examination, but are distinctly psychopathic, others are both psychopathic and sub-breathers. Very few indeed do not fit into one or the other of these categories. Still fewer are not remedied by means of corrective measures which he employs, including a definite series of breathing exercises, carefully calculated to increase the stammerer's use of his lungs.

In this connection it will be recalled that Halle,[23] Gutzmann,[24] Ten Cate,[25] Fletcher[26] and others have studied the breathing habits of stam-

[21] *Op. cit.*

[22] Van Slyke, *Jnl. Biol. Chem.*, 1921, 48, 153.

[23] Halle, *Monats. f. Sprachheilkunde*, X, 1900, 225.

[24] Gutzmann, H., *Monats. f. Sprachheilkunde*, 1908, XVIII, 179. Has also written more than 20 other articles along similar lines.

[25] Ten Cate, M. J., *Monats. f. Sprachheilkunde*, 1902, XII, 247 and 321.

[26] Fletcher, J. M., this JOURNAL, 1914, XXV, 201 ff.

merers in various ways, primarily with reference to the effect upon speech of the gross bodily movements of breathing. One chief difficulty has been that each has apparently attempted to make all stammerers fit into some one specific type, and has not recognized the importance of individual differences and the existence of more than one factor in the etiology of the the defect. Investigators of stammering other than those already cited have apparently neglected the physiological factors entirely, and have applied psychological clinical tests and measurements to stammerers, generally with negative findings. Such an approach is, of course, of a totally inadequate nature. It may be of interest to know the degree of visual imagery or of the intelligence of a stammerer, but—if an individual habitually stammers, he is a stammerer and the stammering *per se* is all-sufficient to diagnose him as a stammerer. Following the diagnosis, in a well regulated clinic, comes the prognosis and prescription of treatment. And here is raised the problem of the metabolic etiology of stammering. It is the etiological factors capable of control which are of primary importance. Dr. Twitmyer has found that certain breathing exercises, together with other drill work, result almost invariably in improvement of the general bodily tone and concomitantly of the speech of stammerers for whom he has prescribed them, on the basis of his diagnosis of them as sub-breathers. Accordingly, at his suggestion and with his cooperation, the writer applied the technique and findings already summarized to a specific study of stammerers applying to his clinic for treatment.

The primary purposes of the research were:

1. (*a*) To determine whether or not such stammerers as showed evidence, in physiological and psychological examination, of being sub-breathers were actually overloaded with carbon dioxide, which would be indicated by the hydrogen ion concentration and carbon dioxide content the mixed saliva; and conversely

(*b*) To determine if the hydrogen ion concentration of the mixed saliva, in connection with determinations of its carbon dioxide content, might be employed as a diagnostic and prognostic aid in the recognition of sub-breathers as a type.

2. (*a*) To determine whether or not such stammerers as were distinctly psychopathic, and in consequence probably more or less constantly in a state of emotional stress, would show a characteristically low hydrogen ion concentration of the mixed saliva; and conversely

(*b*) To find out if the hydrogen ion concentration of the mixed saliva might be employed as an index of more or less chronic emotional disturbance.

3. (*a*) To determine whether or not hyper-sensitive or hyper-excitable subjects would give evidence of their excitement upon the application of a normally inadequate stimulus, by decrease in the hydrion concentration of the mixed saliva; and conversely

(*b*) To determine if decrease in salivary hydrion concentration might be employed in general as an index of transient emotional excitement.

In more general terms:

1. To investigate the metabolic etiology of stammering, and

2. To ascertain the degree of usefulness of determinations of the hydrogen ion concentration and concomitant carbon dioxide content of human mixed saliva in psychological examinations.

With these specific purposes in view the following research was conducted.[27]

1. *Are clinically diagnosed sub-breathing stammerers overloaded with carbon dioxide, and may the hydrogen ion concentration, in connection with the carbon dioxide content of the mixed saliva, be employed as an index of sub-breathing?* Fifty-eight subjects applying to the Speech Clinic for treatment and diagnosed as sub-breathers were examined as follows. The subject was seated in a comfortable chair and told to allow a mouthful of saliva to collect in his mouth, without chewing or other stimulation of the salivary glands. At the expiration of 5 min. he was directed to eject the accumulated saliva into a 15 ml. graduated centrifuge tube. The hydrogen ion concentration of the saliva was at once determined as in the preliminary survey of normal individuals previously described, dibromothymolsulphonephthalein being employed as indicator.[28] Subsequent to the determination of the hydrion concentration, the diluted saliva to which the indicator had been added was aerated in an apparatus previously employed in the biochemical investigations,[29] which involved passing the air through a series of Woulfe bottles and Liebig bulbs containing respectively concentrated sulphuric acid, 30 % sodium hydroxide solution, a tube containing fragments of solid sodium hydroxide, and a small flask containing distilled carbon dioxide free water, prior to it (the air) reaching the saliva through which it bubbled, and washing out the free and loosely combined carbon dioxide which was conveyed by suction into N/5 barium hydroxide solution. The aeration was continued for 45 min., resulting in the formation and separation of a white precipitate of barium carbonate in the tube containing the barium hydroxide solution. Great care was taken throughout to prevent any possible admission of air containing carbon dioxide into the apparatus, and consequently the exact quantity of carbon dioxide thus washed out of the saliva and trapped by the barium hydroxide solution could be ascertained by careful titration of the latter before and after aeration.[30] In every instance, before the period of aeration was completed, the virage of the saliva (with indicator) reached

[27]All of the determinations as regards both sub-breathing and psychopathic stammerers were made upon the subjects when they applied to the Speech Clinic for treatment and *before* they had received corrective treatment. The present research is distinctly with reference to the metabolic etiology of stammering, and the diagnostic value of the salivary pH index. A subsequent research will deal with the results of the treatment given the stammerers by Dr. Twitmyer, as indicated by change in hydrion concentration and carbon dioxide content of the mixed saliva.

[28]Starr, H. E., Biochemical Studies of Human Mixed Saliva, I.

[29]*Ibid.*

[30]*Op. cit.*, I.

or passed neutrality (pH 7.00), while the barium hydroxide solution became turbid, indicating the removal of the carbon dioxide from the saliva. The quantities of carbon dioxide trapped by the barium hydroxide and precipitated as barium carbonate need not be reported, inasmuch as in *every* instance, as just noted above, the hydrogen ion concentration was found to be due to the ratio of free to combined carbon dioxide.[21]

Upon the saliva of the 58 subjects mentioned, 200 determinations were made, distributed as follows: 1 determination each on 18 subjects; 2 determinations each on 8 subjects; 5 determinations each on 29 subjects; 7 determinations each on 3 subjects: thus totalling 200 determinations on 58 sub-breathing stammerers. The results are shown in terms of relative frequency in Table 3.

It is evident from the results presented in Table 3, and shown very clearly in Chart 1, that the sub-breathing stammerers in general and in particular are overloaded with carbon dioxide in their saliva far in excess of the normal individual. Thus the mean, mode and median for the salivary pH of the sub-breathers are respectively 6.00, 5.95 to 6.10, and 6.00, whereas for normal individuals they are respectively 6.8, 6.8 to 6.9 and 6.8. Obviously, therefore, the salivary pH in conjunction with determination of carbon dioxide content by aeration may be employed as an aid in the diagnosis of sub-breathing subjects. That in this series of determinations the salivary pH alone could have been so employed without regard to determination of carbon dioxide content, inasmuch as the latter was always the chief determinant of the former, must by no means be construed as indicating that the latter determination may be safely dispensed with. In the examination of certain distinctly pathologic salivas the writer has found lactic acid present which led to a fairly high hydrogen ion concentration and consequent low pH of the saliva even after prolonged and vigorous aeration, in the course of which comparatively little carbon dioxide was given off. This contingency may be seldom met with, but its possibility renders it absolutely necessary that the saliva be subjected to aeration or other adequate method of determination of carbon dioxide content in connection with the determination of the hydrogen ion concentration of the saliva, if the latter is to be of any diagnostic value whatever.

2. *Do psychopathic stammerers show a characteristically low hydrogen ion concentration and carbon dioxide content of the mixed saliva, and may these salivary biochemical characteristics be employed as indices of chronic emotional excitement?*

[21] See Note 19 *supra*.

Table 3. The Hydrogen Ion Concentration of the Mixed Saliva of Sub-breathing Stammerers, in terms of Relative Frequency

Hydrogen Ion concentration of the mixed saliva	Relative frequency
pH	%
5.4 minus[22]	2.0
5.40	1.0
5.45	1.5
5.50	1.5
5.55	2.0
5.60	1.5
5.65	0.5
5.70	2.0
5.75	4.0
5.80	4.5
5.85	7.0
5.90	7.5
5.95	9.0
6.00	10.0
6.05	8.5
6.10	7.5
6.15	7.0
6.20	6.5
6.25	5.0
6.30	3.5
6.35	2.5
6.40	2.0
6.45	0.5
6.50	1.0
6.55	0.5
6.60	1.5

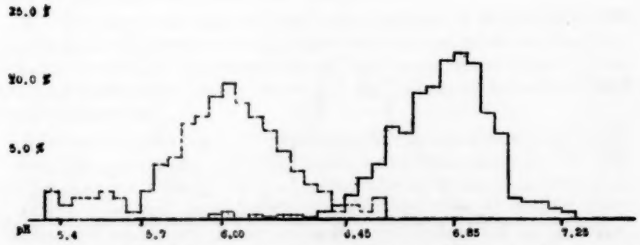

CHART 1. The hydrogen ion concentration of the mixed saliva of sub-breathing stammerers and of normal individuals
Abscissa: Hydrogen ion concentration in terms of pH
Ordinate: Relative frequency in terms of per cent
———— indicates normal individuals
— — — — — indicates sub-breathing stammerers

[22]Inasmuch as the lower limit of accuracy of the indicator employed is pH 5.40, specimens showing a virage indicating a lower pH are reported imply as "pH 5.40 minus."

Table 4. The Hydrogen Ion Concentration of the Mixed Saliva of Psychopathic Stammerers, in Terms of Relative Frequency

Hydrogen ion concentration of the mixed saliva	Relative frequency
pH	%
6.90	2.0
6.95	2.0
7.00	---
7.05	---
7.10	---
7.15	2.0
7.20	4.0
7.25	---
7.30	4.0
7.35	2.0
7.40	4.0
7.45	6.0
7.50	6.0
7.55	10.0
7.60	14.0
7.65	12.0
7.70	10.0
7.75	8.0
7.80	6.0
7.85	2.0
7.90	4.0
7.95	---
8.00	2.0

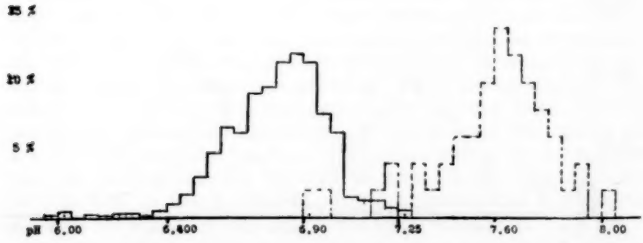

CHART 2. The Hydrogen Ion Concentration of the Mixed Saliva of Normal Individuals and of Psychopathic Stammerers

Abscissa: Hydrogen ion concentration in terms of pH
Ordinate: Relative frequency in terms of per cent
———————— indicates normal individuals
— — — — — indicates psychopathic stammerers

A series of determinations similar to those just described as having been made on sub-breathers was applied to 10 distinctly psychopathic stammerers, embracing 50 determinations distributed thus: 2 determinations each on 2 subjects, and 6 determinations each on 8 subjects. The results are presented in Table 4 and in Chart 2.

Table 4 and the accompanying Chart 2 show clearly that the hyperexcitable psychopathic stammerers examined had a much lower hydrogen ion concentration and carbon dioxide content of the mixed saliva than have normal healthy individuals. With the exception of one psychopathic sub-breather, whose salivary pH was on one occasion 6.90 and on another 6.95, every specimen examined was between pH 7.15 and 8.00. The mean, mode, and median were respectively 7.70, 7.55 to 7.75, and 7.60. Eighty per cent of the specimens were above pH 7.25 and below 7.95. It appears evident, therefore, that the psychopathic stammerer is in general so hyperexcitable that his emotional balance, such as it is, is upset by the mere act of furnishing a specimen of saliva, or that he is in a state of chronic excitement. Probably both conclusions are true. For whether apparently upset or not, the psychopath's salivary pH was almost invariably far above the normal limits, and even exceeding those found obtaining in normal individuals when intensely excited. That the majority of these subjects were abnormally perturbed by the mere presentation to them of the saliva collection tube was indicated by their turning away their heads, flushing, etc. This behavior was in marked contrast to the usually more or less dull and sodden "spitting" of the typical sub-breather. These findings, then, would also indicate that a persistently high salivary pH is an index of more or less chronic emotional excitement.

3. *Do hyper-excitable subjects show evidence of their excitement by concomitant decrease in hydrogen ion concentration and carbon dioxide content of the mixed saliva, and may these salivary biochemical characteristics be employed as indices of transient emotional excitement?*

The sub-breathing and psychopathic stammerers employed in the two preceding investigations were examined in the following manner. Each subject, after the ejection of a mouthful of saliva (the pH and carbon dioxide content of which were determined as before described), was excited as far as possible by verbal goading of a stereotyped form. This goading was not such as would be offensive to a normal individual, but was quite enough to disturb a hyper-excitable or psychopathic subject. It was continued for 5 min., when the collection tube was again presented to the subject, and he was directed to eject into it all of the saliva now in his mouth. (In four in-

TABLE 5. The Effect of Verbal Goading upon the Ability to Speak and the Hydrogen Ion Concentration of the Mixed Saliva of Sub-breathing Stammerers

No.	Before goading			After 5 min. goading				After 10 min. rest period			
	Salivary pH	Ability to speak within 1′	Ability to speak within 2′	Salivary pH	Diff. from initial pH	Ability to speak within 1′	Ability to speak within 2′	Salivary pH	Diff. from pH during goading	Diff. from initial pH
1	5.40	—	+	5.40	0.00	—	+	5.40	0.00	0.00
2	5.50	—	+	5.55	+ 0.05	—	+	5.55	0.00	+ 0.05
3	5.60	—	+	5.75	+ 0.15	—	+	5.65	— 0.10	+ 0.05
4	5.65	+		5.60	— 0.05	+		5.60	0.00	— 0.05
5	5.75	+		5.80	+ 0.05	—	+	5.70	— 0.10	— 0.05
6	5.75	+		5.65	— 0.10	+		5.60	— 0.05	— 0.15
7	5.80	+		5.85	+ 0.05	+		5.85	0.00	+ 0.05
8	5.85	—	+	6.00	+ 0.15	+		5.80	— 0.20	— 0.05
9	5.85	+		5.85	0.00	—	+	5.85	0.00	0.00
10	5.85	—	+	5.90	+ 0.05	—	+	5.90	0.00	+ 0.05
11	5.90	—	—	6.00	+ 0.10	—	+	5.90	— 0.10	0.00
12	5.90	—	+	5.90	0.00	+		5.90	0.00	0.00
13	5.90	+		5.95	+ 0.05	+		5.95	0.00	+ 0.05
14	5.90	+		5.90	0.00	—	+	5.85	— 0.05	— 0.05
15	5.95	+	—	6.15	+ 0.20	—	+	5.95	— 0.20	0.00
16	6.00	—	+	6.20	+ 0.20	—	+	6.05	— 0.15	+ 0.05
17	6.00	+		6.00	0.00	—	+	6.00	0.00	0.00
18	6.00	+		6.05	+ 0.05	+		6.05	0.00	+ 0.05
19	6.20	—	+	6.20	0.00	—	+	6.20	0.00	0.00
20	6.20	—	+	6.45	+ 0.25	—	+	6.25	— 0.20	+ 0.05
21	6.25	—	+	6.20	— 0.05	+		6.20	0.00	— 0.05
22	6.30	—	+	6.30	0.00	+		6.30	0.00	0.00
23	6.30	+		6.25	— 0.05	+		6.25	0.00	— 0.05
24	6.35	+		6.40	+ 0.05	—	+	6.35	— 0.05	0.00
25	6.40	+		6.50	+ 0.10	+		6.35	— 0.15	— 0.05
26	6.50	—	+	6.50	0.00	+		6.50	0.00	0.00
27	6.60	—	+	6.90	+ 0.30	+		6.50	— 0.40	— 0.10
Total	161.95			Total 163.20				Total 163.25		
	27)161.95			27)163.20				27)163.25		
average	6.00			average 6.04				average 6.05		

stances, when the mouth was dry, the subject was urged to expectorate as soon as possible, and the required 1 cubic cm. was forthcoming within 1.5 min.) The subject was then immediately ordered to say "yes, sir," and his ability to say it within 1 or 2 min. was carefully noted, as being largely indicative of the extent of his emotional disturbance. The saliva ejected immediately after the goading was examined in the same manner as the former specimen, and the subject was allowed a 10 min. period of quietude during which to calm down. Then, after a few remarks, calculated to prevent excitement as far as possible, he was again required to say "yes, sir," the time consumed being again noted, and his saliva was again examined as before.

The experiment was conducted on 37 subjects, of whom 27 were decided sub-breathers and 10 unquestionably psychopathic. In no instance do the data presented include more than one investigation of the same individual. For it is obvious that, having once experienced the goading and ascertained its purpose, subsequent repetition of the experiment upon a subject would not have had an effect comparable with that upon one not thus initiated.[33] The results obtained are presented interpretatively in Tables 5 and 6.

SUMMARY OF TABLE 5. Sub-breathers.

Average initial hydrogen ion concentration of the mixed saliva = pH 6.00
After 5 min. verbal goading:
- Average hydrogen ion concentration of the mixed saliva = 6.04.
- 14.8% of the subjects showed a slight decrease in salivary pH, ranging from 0.05 to 0.10, and averaging 0.06.
- 29.6% of the subjects showed no change in salivary pH.
- 55.6% showed a slight increase, ranging from 0.05 to 0.30, and averaging 0.12.

After 10 min. period of quietude:
- Average hydrogen ion concentration of the mixed saliva = 6.05.

Difference from salivary pH immediately after goading:
- 55.6% of the subjects showed no change in salivary pH.
- 44.4% of the subjects showed a slight decrease, ranging from 0.05 to 0.40, and averaging 0.15.
- Average change in salivary pH for the group was minus 0.065.

Difference from initial salivary pH:
- 33.33% of the subjects showed a slight decrease, ranging from 0.05 to 0.15, and averaging 0.067.
- 37.04% of the subjects showed no change.
- 29.63% of the subjects showed a slight increase, which in every instance was 0.05.
- Average change in salivary pH for the group was minus 0.007.

[33] In a subsequent investigation we expect to make a series of similar examinations of the degree of emotional stability or instability, expressed in terms of change of salivary pH due to an emotionalizing stimulus comparable to the initial verbal goading, of the same subjects when they are ready for discharge as cured from the Clinic, to determine the stabilizing value of the corrective treatment they have received.

TABLE 6. The Effect of Verbal Goading upon the Ability to Speak and the Hydrogen Ion Concentration of the Mixed Saliva of Psychopathic Stammerers

	Before goading				After 5 min. goading				After 10 min. rest period			
	Salivary pH	Ability to speak within			Salivary pH	Diff. from initial salivary pH		Ability to speak within	Salivary pH	Diff. from pH during goading		Diff. from initial salivary pH
No.		1′	2′					1′ 2′				
1	6.80	—	+	— —	7.15	+	0.35	— +	6.90	—	0.25	+ 0.10
2	7.30	—	—	— —	8.10	+	0.80	— —	7.80	—	0.30	+ 0.50
3	7.50	+		— +	7.70	+	0.20	— +	7.55	—	0.15	+ 0.05
4	7.50	—	+	— —	8.00	+	0.50	— +	7.60	—	0.40	+ 0.10
5	7.65	—	+	— —	8.00	+	0.35	— +	7.70	—	0.30	+ 0.05
6	7.65	+		— +	7.75	+	0.10	+	7.60	—	0.15	— 0.05
7	7.70	—	+	— —	8.10	+	0.40	— +	7.60	—	0.50	— 0.10
8	7.50	—	+	— —	7.95	+	0.45	— —	7.80	—	0.15	+ 0.30
9	7.35	—	+	— —	7.65	+	0.30	+	7.35	—	0.30	+ 0.00
10	7.40	+		— —	7.95	+	0.55	— —	7.75	—	0.20	+ 0.35
Total	74.35				Total 78.39				Total 75.62			
	10)74.35				10)78.39				10)75.62			
Average	7.44				average 7.84				average 7.56			

SUMMARY OF TABLE 6. Psychopaths.

Average initial hydrogen ion concentration of the mixed saliva = 7.44.

After 5 min. verbal goading:

Average hydrogen ion concentration of the mixed saliva = 7.84.

100% of the subjects showed an increase in salivary pH, ranging from 0.10 to 0.80, and averaging 0.40.

After 10 min. period of quietude:

Average hydrogen ion concentration of the mixed saliva = 7.56.

Difference from salivary pH immediately after goading:

100% of the subjects showed a decided decrease, ranging from 0.15 to 0.50, with an average of 0.27.

Difference from initial salivary pH:

20% of the subjects showed a slight decrease, averaging 0.075.

10% of the subjects showed the same salivary pH as before the goading.

70% of the subjects showed a higher salivary pH than before the goading, the increase ranging from 0.05 to 0.50, and averaging 0.21.

Average change in pH for the group = plus 0.13.

(*a*) The first point that we notice in considering the data presented in Tables 5 and 6 is that the average initial salivary pH of the sub-breathers is 6.0 and that of the psychopaths 7.4, indicating the same fact made evident in Tables 3 and 4, *i. e.*, that the sub-breathers show a salivary pH in general considerably below, and the psychopaths display one considerably above, that of the normal individual (approximately 6.8).

(*b*) The next striking differentiation to be noted is that as a group the sub-breathers showed practically no change in salivary pH as the result of the verbal goading. (The average change for the group was only + 0.057.) A change of less than 0.10 in salivary pH may be regarded as negligible. The few subjects who did show noticeable change—especially nos. 20 and 27, whose salivary pH increased respectively 0.25 and 0.30—displayed hyper-excitability and more or less decided neurotic tendencies to such a degree that at the outset it was difficult to decide whether to list them with the sub-breathers or the psychopaths. It will be noted that they were both totally unable to say "yes, sir" within 2 min. after the cessation of the goading. Subjects 15 and 16, showing an increase in salivary pH of 0.20, were not psychopathic, but were hyper-excitable. Both displayed a somewhat exaggerated patellar reflex (as did also nos. 20 and 27, to an even more marked degree). Neither was able to say "yes, sir" within the stipulated 2 min. The sudden opening of a door behind him in the office where he was seated, presumably comfortably, for the collection of a specimen of saliva, caused no. 16 to start perceptibly.

The psychopaths in general showed a pronounced increase in salivary pH following the verbal goading. In every instance there was an increase ranging from 0.10 to 0.80, with mode and

median approximately 0.4 and a mean of exactly 0.4. That a high degree of excitement resulted from the goading was amply demonstrated by the behavior of the psychopaths. All except nos. 3 and 6 (who showed an increase in salivary pH respectively of only 0.20 and 0.10) were unable to respond to the command to speak with more than voiceless twitching of the lips for more than 2 min. No. 6 forced out the required "yes, sir" in 1′ 22″ accompanying it with a determined shake of the head.

It is thus quite evident that, both as regards the psychopaths and the sub-breathers, emotional disturbance and increase in salivary pH went *pari passu*.

(*c*) The third differentiation brought out by this investigation was with regard to decrease in salivary pH upon subsidence of the emotional excitement. After the 10 min. period of quietude, all of the sub-breathers succeeded in enunciating "yes, sir" within the required 2 mins., with the exception of no. 27, who took 2′ 28″. Nos. 20 and 26 succeeded in the test barely within 2 min. Each one of the three subjects had displayed under goading a rather high degree of hyper-excitability, indicated by marked rise in salivary pH and concomitant decrease in carbon dioxide content of the saliva. In connection with this ability to speak after the period of quietude, noted in the majority of the sub-breathers, it may be remarked that the final salivary pH of each of them, except no. 27, was practically identical with his initial salivary pH.

The psychopaths, however, varied greatly among themselves as to their ability to pronounce "yes, sir" after the 10 min. period of quietude. It required 4′ 18″ for no. 2 to get it out, which might have been anticipated from the fact that his final salivary pH was 0.5 higher than his initial one. Subject 6 responded with the test words almost immediately when requested to do so. Under goading his salivary pH had increased only 0.10, and after the rest period it was practically the same as at the beginning of the examination. Nos. 8 and 10 were unable to speak within the 2 min. limit. The salivary pH of each at this time was still respectively 0.30 and 0.35 above the initial pH. No. 9 required 59″ to get out the test words. The others required more than 1′ and less than 2′. It is evident, therefore, that the psychopathic stammerers not only become more easily excited than do the sub-breathers, but that in the main their excitement subsides more slowly,—or is reestablished much more readily. For it is difficult to say definitely whether the psychopaths, whose final salivary pH was above their initial pH, were *still* excited or *again* excited.

It would appear from these tests that the hydrogen ion concentration of the mixed saliva, when its fluctuations are due to variations in the quantity of carbon dioxide present, as was the

case in every one of the foregoing analyses, may be employed to determine the relative excitability of an individual.

Application.—The tests already described were applied to a group of 7 stammerers who showed little if any anatomical indication of defective breathing and who were not psychopathic. The results are presented in Table 7.

TABLE 7. Examination of Seven Unclassified Stammerers

	Before goading				After 5 min. goading				After 10 min. rest period			
No.	Salivary pH	Ability to speak within 1′	Ability to speak within 2′		Salivary pH	Diff. from initial PH	Ability to speak within 1′	Ability to speak within 2′	Salivary pH	Diff. from pH under goading		Diff. from initial pH
1	6.10	+	+		6.15	+ 0.05	+		6.15	0.00		0.05
2	6.30	—	—	+	6.25	— 0.05	+		6.25	0.00		—0.05
3	6.85	+	+		6.90	+ 0.05	+		6.85	— 0.05		0.00
4	6.95	+	+		6.90	— 0.05	+		6.95	+ 0.05		0.00
5	6.95	— +	—	—	7.35	+ 0.40	—	—	7.15	— 0.20		+0.20
6	7.00	— +	—	+	7.30	+ 0.30	—	+	7.10	— 0.20		+0.10
7	7.35	— +			7.65	+ 0.30	—	+	7.40	— 0.25		+0.05

Interpreting Table 7 in the light of the preceding findings we may diagnose nos. 1 and 2 as not hyper-excitable sub-breathers; nos. 3 and 4 as neither sub-breathers, psychopathic, nor hyper-excitable (no. 4 was, in fact, an old case about ready for dismissal from the Speech Clinic as Cured); nos. 5 and 6 as hyper-excitable; and no. 7 as hyper-excitable and probably more or less psychopathic.

SUMMARY

As a result of this research, involving about 1300 salivary analyses and psychological diagnostic judgments, what has been found?

First, as to stammerers. There is one group of stammerers, embracing 73.7 per cent of the stammerers examined in the general survey of those who applied for aid to the Speech Clinic of this University during the scholastic year of 1921-22, who may be denominated as sub-breathers and who have their organisms overloaded with carbon dioxide. As a consequence their mental faculties are dulled, they are always working in a "fatigued" condition, virtually under pressure. Until the carbon dioxide content of their blood has been reduced more nearly to normal limits it is practically hopeless for them to attempt to break any old habits or acquire any new ones, whether of speech or otherwise. Proper breathing exercises in the open air adapted to the individual's requirements should be of immense value in this connection.[34] A decrease in the carbohydrate content of the diet should also prove of benefit.

[34]A series of experiments is now in progress to determine the efficacy in freeing the system of excess carbon dioxide by means of certain specific breathing exercises.

Another, and considerably smaller group of stammerers are distinctly psychopathic,—somewhat less than 15.4% of those examined in the present research. These subjects are generally very hyper-excitable. They discharge a disproportionate amount of energy in response to an immediate stimulus, displaying no sense of proportion. A stimulus which would have very little effect upon a normal subject, and none at all upon a typically dulled sub-breather, upsets the "equilibrium" of a psychopath completely. They are practically hopeless subjects for remedial measures, so far as correction of their speech defect is concerned, unless their general psychopathic condition is first cured. For while they may respond with all their power to the stimulus of treatment, in the way of exercises, drill, etc., in the presence of the teacher, there is little if any apperceptive residuum left. Once out of sight of the Clinic, what they have there done and been told to do is speedily eradicated from their minds by fresh stimuli, to which they respond with the same disproportionate display of energy.

Obviously another type of stammerer may be both hyper-excitably psychopathic and a sub-breather. Such a subject in a hyper-excited condition might eject a saliva apparently normal as to pH, inasmuch as his sub-breathing habits would tend to keep his salivary pH low, while his hyper-excited condition would tend to raise it. Between the two contending factors, the salivary pH, at some given moment when the specimen is collected and the determination made, may be occupying a median position approximating that of a normal saliva. An adequate series of determinations, however, should show his predominant tendency, and the series of tests with and without verbal goading will serve to indicate his degree of excitability.

A fourth group of stammerers may not be dulled by defective breathing or other cause of overloading the system with carbon dioxide, resulting in chronic "fatigue" and concomitant lack of energy, nor may they be psychopathic. They may simply be hyper-excitable. Perhaps it is from this class that the psychoanalyst recruits his subjects.

In the light of our findings as to the metabolic etiology of stammering, we may sum up the therapeutic measures indicated by stating that the sub-breathers must be toned up and their systems freed from excessive carbon dioxide by a technique probably involving vigorous breathing exercises and a control of the diet, in addition to the regular drill; the hyper-excitables must be calmed down; and the psychopaths—sent first to a psychiatrist.

As to the hydrogen ion concentration of the mixed saliva in conjunction with determinations of the carbon dioxide content, the present research has found it useful as an index of

(1) the condition of an individual as to fatigue or energy at his disposal, and the breathing habits of the individual;

(2) the degree of emotional excitement under which the subject is laboring at the time of the determination—thus enabling the constantly excited psychopath to be readily detected; and

(3) the degree of excitability of an individual, by means of a series of determinations made before, during and after the application of a definite emotionalizing stimulus.

The question remains why the hydrogen ion concentration of the mixed saliva, due to the presence of carbon dioxide, is abnormally high in sub-breathers and fatigued individuals, and abnormally low in chronically excited psychopaths. And why in excitement does the salivary pH tend to rise in both normal and abnormal individuals? No dogmatic answer may be given. It would appear, however, that the explanation is somewhat as follows. As a result of either sub-breathing, muscular exertion, or excessive ingestion of carbohydrates, carbon dioxide accumulates in the blood and in the alveolar air in excess of the normal tension. The result is, *normally*, a certain degree of hyperpnoea to relieve the tension, for carbon dioxide is a specific stimulus of the respiratory center as are also lactic acid and other products of fatigue,[35] the teleology of the hyperpnoea being to expel enough carbon dioxide so that normal limits may again be reached. The consequence is that normally the carbon dioxide content of the alveolar air varies but little in an individual, an increase in carbon dioxide content of the blood resulting in augmented respiration rather than in accumulation of carbon dioxide in the alveolar air. There is, however, some increase in the latter, and, as we have found, the salivary hydrion concentration increases as the carbon dioxide content of the alveolar air increases, but to a greater degree. Consequently, a high hydrion concentration of the saliva, when due to carbon dioxide, indicates a high carbon dioxide content of the alveolar air, and therefore of the blood. A high carbon dioxide content in the blood manifests itself in fatigue, dullness, inertia.[36] This concomitant excitation of the respiratory center and dulling of the centers stimulating the individual to activity has probably developed ontogenetically because of its phylogenetic import. For when there is a great accumulation of carbon dioxide throughout the organism, further activity might endanger life, and the individual would probably keep going until he inadvertently committed suicide. But fatigue, inertia, dullness, lead him to a cessation of carbon dioxide producing effort, and meanwhile the stimulation of the respiratory center, as noted, normally leads to expulsion of the excess carbon dioxide, and a return to normal conditions of the blood and system in general. It is possible in the case of the most pronounced sub-breathing stammerers, or other individuals with markedly high salivary hydrion concentrations due to the presence of carbon dioxide in the saliva, that in addition to, or in the absence of, pernicious breathing, working, or dietary habits *per se*, there may be a lack of sensitivity of the respiratory center, so that the carbon dioxide may accumulate in the blood leading to a chronic fatigue, or even somewhat of a mental numbness, without the normally concomitant hyperpnoea to rid the system of the excess carbon dioxide. In this event, also, very vigorous breathing, deliberately and regularly practised (a sort of artificial hyperpnoea) may be of great remedial value.

[35]Cf. Robertson, T. B., Principles of Biochemistry. N. Y. and Phila., 1920. Pp. 364-368.

[36]For the toxicology of carbon dioxide see Kobert, R., Lehrbuch der Intoxikationen, II. Stuttgart, 1906. Section on Kohlensäure, pp. 1120-23.

With regard to the problem why the psychopaths examined showed constantly such abnormally low hydrogen ion concentration of the mixed saliva (and consequent high pH), we must again avoid dogmatic assertion. Their practically chronic emotional excitement, whether or not displayed by overt acts, suggests that the same physiological etiology obtains as in the case of any subjects, normal or abnormal when their salivary pH increases during emotional stress. This may be attributed largely to the hyperpnoea, amounting in high degrees of excitement to a veritable dyspnoea, which rids the alveolar air (and consequently the blood) of a large part of its carbon dioxide content. In psychopathic subjects the respiratory center *may* be abnormally sensitive to relatively small quantities of carbon dioxide in the blood, or there *may* be abnormal activity of the adrenals resulting in excessive quantities of adrenin in the blood, causing a more or less chronic dilatation of the bronchioles and thereby diminished carbon dioxide tension of the blood and alveolar air. In either or both cases the result would be decreased carbon dioxide content of the mixed saliva and consequent lower hydrogen ion concentration, indicated by increased salivary pH.

In normal individuals the functioning of the adrenals in times of emotional stress is probably a prime factor in the stimulation of the respiratory center and dilatation of the bronchioles. In other words, in emotional excitement the functioning of the adrenals prepares the organism for flight or fight by ridding the system to a greater degree than usual of carbon dioxide, and preparing it for the speedy removal of the excessive quantities of carbon dioxide which would result from intense exertion. The teleology of the function is the prevention or postponement of fatigue and exhaustion. When the prepared-for exertion does not follow, the carbon dioxide content of the blood and of the alveolar air probably remains for some time below the normal limits, with the result that there is an even more greatly diminished carbonic acid content and consequently lowered hydrogen ion concentration of the mixed saliva, indicated by a high salivary pH.

LAUGHTER, A GLORY IN SANITY

By Ransom Carpenter

In offering a theory of laughter to the judgment of psychologists I must begin by explaining that I am not myself a psychologist, and that in preparing the matter here following I have necessarily written as if addressing readers of my own nontechnical level.

Without knowing (or possibly having forgotten) that the nature of the comic was a favorite riddle of philosophers, I reached an answer that satisfied my own curiosity, and later went to a library to consult the authorities. My impression grew, the more I read, that in the attempt to explain so universal, familiar, and open a phenomenon as laughter there was a tendency to resort to solutions either limited in scope or abstruse and indirect in their application. The true answer, I thought, must needs be as broad and simple as laughter itself; yet the exertions of printed philosophy seemed to display an unaccountable strain toward the narrow and complex.

That there are manifold mental complexities underlying and surrounding the act of laughter I do not question. That field remains for better equipped explorers. I simply place on view a bit of mental mechanism which, when once pointed out, I believe brief introspection will identify to any thinker as the main actuating principle of laughter, but which for some mysterious reason has eluded the notice of other inquirers.

Indeed I cannot suppose that no one else has formulated, at least to himself, so simple a principle. I only know that a fairly careful search of available publications,[1] including recent copious works that review the prior field exhaustively, has failed to disclose a single line that definitely anticipates my explanation.

Now I shall try to state, in my own way, and so far as possible without reference to any preceding theory, what it seems to me that laughter is. Laughter is the outcry of the soul exulting in sanity. Or, more soberly and completely, laughter expresses an emotion due to a sudden flooding into consciousness of the subconsciously abiding pleasure in the power of judgment, occasioned by the swift overthrow of presented propositions that tend but fail to delude the judgment.

The possession of reason is obviously good cause for continuous elation, and we do in fact rejoice in it unceasingly; it is part of that basic joy for which people cling to life despite any miseries. But our realization of it, like that of other glories, is glossed over with practical habit. We are used to it. So long as the path of thought is plain and even, we walk in it soberly, exercising our cherished judgment as a matter of course, accounting unconsciously for the multitude of facts or ideas presented, finding them in order, coherent with sanity. But let a pitfall of absurdity appear in the

[1] Schopenhauer, A., The World as Will and Idea, iii, VIII, On the Theory of the Ludicrous.
Bergson, H. L., Laughter; an Essay on the Meaning of the Comic; Brereton and Rothwell's trans., 1911.
Sully, James, An Essay on Laughter, 1902.
Freud, Sigmund, Wit and Its Relation to the Unconscious; Brill's trans., 1916.
Sidis, Boris, The Psychology of Laughter, 1913.
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Eastman, Max, The Sense of Humor, 1921.

pathway, so that the mind at the same moment sees where it might have slipped yet walks erect; then the sense of sanity swells abruptly into sharp emotion that is voiced in laughter.

Why a glory in sanity should find expression in spasmodic noises is, of course, a question of physiology, with an answer lying somewhere in the long history of bodily evolution. It does not concern my purpose, which is to show what laughter is within us, the nature of the comic sense.

To make the matter clearer let us examine, in the light of this explanation, the nature of the things and ideas that provoke laughter. Why, let us ask, is one notion funnier than another?

To be comic, a proposition must be (1) perceived as false, and (2) perceived as deceptive. These are the essentials. Actually to excite laughter, it must generally also (3) be suddenly presented, and (4) have a free field, in which its effect is not submerged by stronger emotions.

An idea is most comic when all these factors are most favorable. The height of the ludicrous is reached by what is wild, yet plausible. The wilder and more plausible the rejected idea, the more sharply it throws open the valve that lets out a gust of elation at reason's triumph. The virtue of a moderately good joke may lie either in an extreme falsity with a slightly deceptive element, or in an approach to truth so near that it almost convinces. The two elements, of course, may both be of moderate force, or one or the other may dwindle within the realm of bad jokes to the vanishing point, leaving accepted truth or bare falsehood, neither of which is funny.

In one of the treatises that I examined[2] there is an inconclusive discussion of a previous writer's effort to penetrate the mystery of the comic aspect of a child wearing his father's hat. This example will serve as well as any for first pointing out the virtues of my solvent. We smile at this mildly funny sight because the child's pretense offers to our mind the obviously false proposition, "This hat might make you think me a man," and there is just enough plausibility in the idea for the act of rejecting it to remind us faintly of the fact that we are sane. That is all there is to the mystery.

Another favorite query of investigators is why a grotesque mask is funny. Here the falsity presented may be expressed as "There might be such a person as this," or "People are like this," and the deceptive element is obvious. The spectator's mind is put on the alert against any yielding, perhaps momentary or half conscious, to the offered illusion, and the pleasure which the ego takes in this resistance is nothing more or less than the sense of the comic.

Again, the writers often ask why we should laugh at the fall of one who slips or stumbles. Some even gloomily attribute to laughter, on this ground, a cruel or debasing element. Nothing could be more opposed to truth. If the fall is really cruel, the normal person does not laugh. A comic fall is one that presents a delusive aspect of catastrophe, which we instantly recognize as unreal, relishing the recognition. The more "scary" the fall, the greater is the exertion of judgment and the more we exult. As for the abnormal person who laughs at another's pain or misery, his subconscious point of view may be thus expanded: "That old woman's fall might be supposed to excite pity, but being superior to such weak sentiments I am not deluded." So he triumphs in his own peculiar kind of sanity.

A child's laughter should offer clarifying examples. I remember being startled, long before I had thought the matter out, by observing how my daughter, then less than two years old, laughed most merrily at just those antics of a playful kitten that I myself found most diverting. Now I see that within the scope of the child's experience she had as good a right as I to triumph in the exercise of judgment, and more reason, because judg-

[2] Sully, *op. cit.*, 9-17.

ment was for her, so to speak, a newer plaything. The kitten by its capers repeatedly suggested that it was all the same as a real person, which the baby knew perfectly well was not true. The kitten's best moments as a comedian were those in which it most plausibly mimicked some human trait or purpose. If the impersonation had at any point become convincing, the baby would not have laughed. She might rather have been frightened out of her wits. But being well in possession of her wits, and using them vigorously to combat the kitten's wild assertions, she naturally rejoiced aloud.

A child who thus takes pleasure in thrusting off persuasive untruths soon learns to build up fictions for the fun of demolishing them. So we have play, which Sully considered almost identical with mirth. The true relation will now be manifest. Laughter is by no means always derived from play, but only when the plausible falsity that provokes it is framed with intention to create amusement. The pleasure of play (so far as it is "make-believe") resides precisely in our continuous perception of its unreality, and we enhance the realism of our play only so as to gloat the more in that perception.

One of the sources of the comic before which the cloud of mystery seems to have hung with a peculiar allurement may best be indicated by the general label "breaches of decorum." Analysis of one innocent example will serve to sweep away the fog from all, without, let us hope, dispelling any of their charm. Let us consider a man who snores in church, and why he is funny.

The atmosphere of a church may be put in the form of an assertion: "This is a solemn place where everyone is always quiet and attentive." The incongruous snore abruptly compels rejection of this proposition as merely plausible, at the same time offering the counter suggestion, "This man owes no reverence," which the mind as promptly dismisses because the disturbance is unintended and unimportant. Thus the ego's triumph lies partly in detecting the flaw in the church's veil of solemnity, and partly in perceiving the inconsequence of the defect.

The reader with a particular interest in this direction will find it easy to extend the principle to profanities, indecencies, tribal taboos, sexual lapses, and similar items the discussion of which has tended to impart a mystic air to anthropology. In every instance of the kind judgment will be found striking a balance between opposed pretensions of "decorum" or law, on the one hand, and the "breach" or liberty, on the other, and glorying in the sane escape from both.

In the few foregoing instances, I have tried to reduce the material to the simplest possible terms, to exhibit the working of the formula. Indeed the barest outline will suffice to diagram a multitude of jokes, including many good ones. But the laughable proposition may be double or complex, and generally it wears a fringe of implied comicalities, vague or subtle perhaps, but always enriching. Humor, I suppose, resides in such broad and indefinite implications, often conveyed by statements in no way comic of themselves, whereas wit is sharp, simple, and direct in outline. For illustration, let us glance at this yarn from a random newspaper:

"There is a philosophic old colored barber in Washington who is much patronized by statesmen. They find much that is edifying in his conversation.

"One day the old fellow, being in an especially talkative mood, made this observation to a newly arrived representative from the West:

" 'Yo' has a large head, suh. It's a good thing to have a large head, fo' a large head means a large brain, an' a large brain is de most useful thing a man kin have, fo' it nourishes de roots of de hair.' "

The mainspring of the joke is in the last twenty words, which by themselves form a good single specimen of wit, assuming they were intended playfully. Yet they convey at least two main delusive falsehoods, the

instant double overthrow of which reassures us of sanity and unlooses elation. One may be put as "Brains nourish the roots of the hair;" the other as "The use of brains is to grow hair." But our laughter is the keener because of the beautifully laid approach to the pitfall, which remains invisible up to the very last words. The effect is also richer for a variety of comic elements that are only suggested or implied, involving, let us say, the known peculiarities of congressmen and of barbers, perhaps also of colored persons and of philosophers. Each of these elements could readily be dissected out and placed in the form of a plausible fallacy, contributing by its downfall to the glow of reason's satisfaction.

One is tempted to speculate on the social value, if any, of knowing what laughter is. I think it truly matters, but here a word in closing must suffice. I have mentioned how some writers have found cruelty and malice lurking in the happy faculty, and this is not the only charge laid against it. Hobbes' definition[3], so apt in the phrase "sudden glory," has yet played a most unfortunate part in misleading later analysts, through the reference to "comparison with the infirmity of others" as the spring of laughter. Because Hobbes failed to perceive that in mirth the mind glories in its own successes, by comparison with nothing but its own avoided errors, a long train of thinkers have tended to look on laughter as implying vanity, arrogance, or selfishness. In point of fact, even when laughter seems to express malice or contempt, it is not the true voice of those emotions, but always of some residual shred of sympathy. Scorn may be expressed without sympathy and without laughter; if laughter enters, it can only mean that the laugher perceives how he might have shared the weakness that he contemns.

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[3]Though frequently quoted, repeated here for comparison: "The passion of laughter is nothing else but sudden glory arising from a sudden conception of some eminency in ourselves, by comparison with the infirmity of others, or with our own formerly."

A NOTE ON HENNING'S SMELL SERIES

By Forrest L. Dimmick, Univ. of Michigan

Henning[1] has given us a thorough discussion of his researches in smell so far as their historical and theoretical aspects are concerned. As Gamble[2] has already pointed out, however, the details of experimentation are very meager. Henning's most striking contribution is, probably, his serial classification of odors; yet nowhere does one find listed the qualities of any considerable part of the 415 stimuli[3] used. At most there are examples of several of the series from the reports that one or another *O* gave; but these examples vary greatly in completeness and, by Henning's own profession, are not unequivocal, but differ from time to time and from *O* to *O*. Anyone who has attempted to make a class-demonstration or an elementary laboratory experiment based on the new classification of odors has come upon these difficulties.

We have attempted to supply in some measure the data which Henning has omitted. Following the example of others[4] we have accepted the Henning prism as a starting-point. From the sample lists of the several series which Henning gives, we have taken all those stimuli that can be readily obtained, 75 in number. Small quantities of the substances were placed in two-drachm bottles which were numbered on the side and on the cork There was no marking on the bottles which could give the *Os* a cue to the nature of the contents, and the numbered labels practically concealed them.

The *Os* knew to start with the general nature of Henning's classification, and they had been given Henning's typical corner odors. Every *O* was required to make one complete classification of the entire set. He was instructed to "choose at random ten stimuli; to smell them one at a time with both nostrils; and to record every particular number under the group heading or headings that best described the odor." Not more than 10 stimuli were smelled at a sitting. The *Os* were, in the main, members of an advanced class which had just taken up the systematic study of olfactory sensation, and of an elementary laboratory class. A few well trained *Os* were included. A total of 16 classifications was made. The first classification made by every *O* is the one taken for our results, inasmuch as our purpose is to find a set of odors that will illustrate the series unequivocally and immediately.

In Table I we have brought together the results of the 16 classifications. In the second column, under H, the designations indicate the approximate classification of the odors according to Henning[5]. The numerical results show the distribution of the classifications made by our *Os*. The greatest number of choices that can be made under a single heading is 16, but a greater total number for a single stimulus may result from its classification as an intermediate odor.

[1]H. Henning, *Der Geruch*, 1916. Printed earlier in the *Zeit. f. Psychol.*, 73-76, 1915, 1916, in four parts.

[2]E. A. Mc. Gamble, this Journal, 32, 1921, 290.

[3]Henning, *op. cit.*, 7.

[4]Gamble, *op. cit.*; E. B. Titchener, this Journal, 31, 1920, 213.

[5]*Op. cit.*, 80-97.

TABLE I

Stim	H	Fl	Fr	Sp	Re	Bu	Fo	Stim.	H	Fl	Fr	Sp	Re	Bu	Fo
Vanilla	Fl	6	11	6	1	1	—	Acetic Ether	ReFr	3	6	—	9	3	1
Jasmine oil	Fl	15	1	—	—	—	—	Ethyl Ether	ReFr	5	5	—	8	2	—
Tonka Bean	Fl	8	—	9	—	—	—	Acetone	ReFr	2	6	2	9	3	1
Apple Blossom*		16	—	—	—	—	—	Collodium	ReFr	1	7	1	9	5	—
Camomile fl.	FlSp	5	—	14	—	2	—	Lemon o.	Fr	—	16	—	1	—	—
Lavender fl.	FlSp	6	6	12	1	—	—	Orange o.	Fr	5	14	—	1	—	—
Origanum o.	FlSp	1	4	3	14	5	—	Citronella o.	Fr	5	6	3	6	2	—
Arnica tin.	FlSp	1	11	2	3	9	—	Bergamot o.	Fr	—	3	4	11	—	3
Hops fl.	FlSp	1	—	8	1	2	9	Amyl-Valerate	Fr	—	15	—	1	—	—
Cumarin	FlSp	10	7	4	1	—	—	Geranium o.	FrFl	9	6	6	6	1	—
Caraway o.	FlSp	1	4	6	6	1	2	Pyridine	Bu	—	—	—	—	8	14
Clove o.	FlSp	3	4	12	2	—	—	Tar	Bu	—	—	—	—	14	2
Bay o.	FlSp	7	5	9	3	—	—	Coffee	BuSp	—	—	9	—	7	—
Thyme fl.	FlSp	3	—	13	—	—	—	Xylol	BuRe	1	1	1	11	6	—
Cassia o.	FlSp	3	3	14	—	—	—	Toluol	BuRe	1	—	1	11	5	2
Pepper	Sp	1	—	14	2	—	—	Benzol	BuRe	1	3	—	9	3	4
Sage	Sp	6	1	11	2	—	1	Fish Soap	Fo	—	—	—	1	3	15
Cinnamon	Sp	1	1	16	—	—	—	Glue	Fo	—	—	—	1	3	16
Ginger	Sp	8	6	5	6	—	—	H_2S†	Fo	—	—	—	1	—	15
Anise o.	SpRe	6	13	8	—	—	—	Ammon.-Valer.*		1	8	1	2	1	7
Marjoram	SpRe	3	—	11	2	—	—	Lactone	FoBuSpFl	4	1	5	2	—	4
Sassafras o.	SpRe	4	8	10	3	—	—	Apiol	FoBuSpFl	2	3	5	5	9	—
Nutmeg o.	SpRe	1	3	12	2	—	2	Asafoetida	FoBuSpFl	—	—	—	1	1	15
Fennel o.	SpRe	4	8	7	7	—	—	Celery Seed	FoBuSpFl	2	2	12	1	—	—
Cardamom	SpRe	2	4	10	8	1	—	Dill Seed	FoBuSpFl	3	1	13	2	—	—
Canada Bal.	Re	2	1	—	11	1	1	Mustard oil	FoBuSpFl	—	3	6	4	—	10
Cedar o.	Re	1	1	4	12	2	1	Guiacol	FoBuSpFl	2	—	—	2	14	—
Juniper o.	Re	—	4	3	11	1	—	Musk Root e.	FoBuReFr	10	—	2	2	4	2
Pine Need. e.	Re	—	1	4	12	—	—	Musk	FoBuReFr	1	5	6	5	6	2
Sandarak g.	Re	2	3	1	9	—	1	Arbor Vitae e.	FlFrSpRe	2	6	4	7	3	—
Spikenard o.	Re	—	2	—	14	2	—	Juniper Ber.	FlFrSpRe	3	3	7	3	1	—
Camphor g.	Re	—	1	5	10	—	—	Tansy o.	FlFrSpRe	3	—	8	9	5	—
Myrrh tin.	Re	4	6	4	3	5	—	Wormwood o.	FlFrSpRe	2	1	8	6	5	1
Turpentine	Re	1	—	—	15	2	—	Peppermint o.	FlFrSpRe	3	6	10	6	—	—
Cajuput o.	Re	—	2	4	13	—	1	Spearmint o.	FlFrSpRe	4	9	6	4	—	1
Rosemary o.	Re	—	4	5	12	—	—	Menthol	FlFrSpRe	—	5	10	3	3	1
Eucalyptus o.	Re	—	1	4	12	—	4	Amyl-acetate*		2	16	—	—	—	4
Lavender o.	Re	3	5	4	9	—	—								
Copaiba Bal.	Re	5	2	9	4	1	—								

Fl = flowery; Fr = fruity; Sp = spicy; Re = resinous; Bu = burned; Fo = foul; fl. = flowers; o. = oil; g. = gum; tin.. = tincture; e. = extract; Bal. balsam; *not classified by Henning; † add a few drops of Hydrochloric Acid to Ammonium Sulphide.

It is evident from the table that valid examples of corner and intermediate odors can not be taken at random from the sample series of Henning. For example *vanilla*, which Henning gives as characteristically flowery, is designated more frequently by our *O*s as fruity; *tonka-bean* is as spicy as it is flowery; while *jasmine oil* is always flowery. There are many similar cases, especially among the intermediate odors. This same multiplicity of similarities is also remarked by Henning[6], and indeed is the basis of his conception of the Smell Prism as a surface figure[7].

Adequately to demonstrate the odor series, then, it is obviously necessary to select those odors which will fall most readily into their proper classes. We have attempted to do this in Table II. In it we have included under the proper headings (1) those stimuli which in at least 70% of the cases our *O*s classify in the same way as Henning, (2) in parentheses those stimuli in whose cases our *O*s do not agree so well with Henning, but are still not at total variance with him, and (3) in italics those stimuli in whose cases our *O*s totally disagree with Henning, but agree significantly among themselves.

TABLE II

Flowery	Fruity	Spicy	Resinous	Burned	Foul
Jasmine o. *Apple Blos.*	Lemon o. Orange o. Amyl-Valerate	Cinnamon Pepper Camomile f.	Spikenard o. Turpentine Cedar o. Pine-Needles Rosemary o. Eucalyptus o. Cajaput o.	Tar *Guiacol*	Fish Soap Glue H_2S *Asafoetida*
Fl-Sp	Sp-Re	Re-Fr	Re-Bu	Fr-Fo	Fr-Fl
Lavender f. Cumarin Cassia o. Clove o. Bay o. *Tonka-bean*	Marjoram Cardamom Nutmeg Sassafras o. Anise o.	Acetic Ether Ethyl Ether Acetone Collodium	Xylol Toluol	*Ammonium-Valerate*	*Orange o.* *Vanilla*
Bu-Sp	Fo-Bu	Fl-Fo	Sp-Re-Bu	Fl-Fr-Fo	
Coffee	*Pyridine*		*Tansy o.* *Wormwood o.*	*Amyl-acetate*	
Fl-Fr-Sp-Re	Fl-Sp-Bu-Fo	Fo-Bu-Re-Fr			
Arbor Vitae Juniper ber. Peppermint o. Spearmint o. *Myrrh*	(Apiol) (Lactone) (Mustard o.) *Hops f.*	*Benzol* (Musk)			

The foregoing table shows the stimuli which may be depended upon to demonstrate every corner, every edge (with one exception), and every surface of the smell prism. The stimuli, in the classification of which we agree with Henning, are to be preferred. Those in italics can be seen by reference to Table I to have been very positively placed by our *O*s and are therefore dependable. We have made no attempt as yet to arrange the intermediate odors serially between end-points. As Henning[8] remarks, a large number of intermediate steps is necessary to demonstrate adequately a psychological series. We hope to be able to duplicate and add to Henning's complete list of stimuli and to make out their serial arrangement.

[6] *Ibid.*, 97.
[7] *Ibid.*, 97.
[8] *Ibid.*, 500.

STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF VASSAR COLLEGE

XLIII. Voluntarily Controlled Likes and Dislikes of Color Combinations

By Margaret Floy Washburn, Margaret T. MacDonald, and Dorothy Van Alstyne

In Vol. XXXII of this Journal, pp. 284 to 289, there was published a study from the Vassar laboratory which was concerned with the effects of instructing observers to try to alter their judgments of the pleasantness or unpleasantness of single colors. The colors were eighteen of the Bradley series, six each of saturated colors, shades, and tints, and were presented in the form of pieces 3 cm. square, each pasted in the middle of a card 2.5 by 3 in. "One of these cards was laid on a table before the observer, who was asked to express her judgment of the pleasantness of the color by using one of the numbers from 1 to 7, 1 meaning 'very unpleasant', 7 'very pleasant', and 4 'indifferent'. When the judgment had been expressed, the experimenter said, 'Now I want you to see if you can dislike that color,' if the judgment had been favorable; or, 'I want you to see if you can like that color,' if the judgment had been unfavorable. The original judgment and the altered judgment were recorded, and the observer was then asked how she had effected the change." About two months later each observer was asked to judge the pleasantness of the colors again. The results of this investigation will be mentioned in connection with those of the present study.

We have undertaken to repeat this procedure exactly, using color combinations instead of single colors.

Thirty-six cards 2.5 by 3 in. in dimensions were prepared. Each card had pasted on it two differently colored squares, 3 cm. a side, of Bradley colored papers. The two pieces of colored paper were directly side by side, in contact, with no intervening space. No principle was used in selecting the components for the color combination. They were divided into two sets of eighteen, one set to be used by each of the two experimenters, and the attempt was made to get into each set some obviously agreeable and some obviously disagreeable combinations. In presenting the cards to the observers, and in instructing the observers, the same procedure was used as in the case of the single colors.

There were in all seventy observers: since each made eighteen judgments, there was a total of 1260 judgments.

The first point to be noted in the results concerns the cases where the observers failed in the effort to change their affective judgments. *A considerably higher percentage of judgments could not be changed when color combinations were used than was the case where single colors were used.* With single colors, the percentage of judgments that could not be altered was 6.3; with color combinations, it was 20.3. A possible interpretation of this result would be that, where the character of the material is the same, the affective attitude is less stable, the simpler its source.

The second point concerns the readiness with which different types of judgment could be changed. Our results *agree with those of the previous study* in showing that *extreme judgments are harder to change voluntarily than moderate judgments.* Of the judgments '1', 29.5% could not be changed; of the judgments '2', 22.4%; of the judgments '3', 11.3%; of the judgments '5', 12.9%; of the judgments '6', 14.7 %; of the judgments '7', 38.5%

Our results *do not*, however, *confirm* the finding of the previous study *that judgments of extreme unpleasantness are harder to change than judgments of extreme pleasantness*; the reverse is true with the color combinations.

Our results *agree* with those of the previous study in showing that *it is easier to lessen the unpleasantness of a color impression by six points than to raise it by six points.* 7.3% of the 1 judgments were raised to 7; 11.4% of the 7 judgments were lowered to 1. We *agree* also in finding that *it is somewhat easier to lessen the pleasantness of a color impression by five points than to raise it by five points*, although the difference here is probably too slight to have significance. 5.3% of the 2 judgments were raised to 7; 8.9% of the 6 judgments were lowered to 1.

Our observers were, like those of the preceding study, asked after a two months' interval to express their judgment of the pleasantness of the color combinations again (no attempt being made to alter them this time).

The first point to be noted here concerns the tendency of the original judgments (made before the effort to change) to recur after the two months' interval. In the case of the single colors, the tendency of judgments of pleasantness to recur had appeared slightly greater than that of judgments of unpleasantness. No such difference appeared in the case of the color combinations.

In the case of the single colors, it was found that "changes *in the direction of increased pleasantness are more likely to be lasting*," where the amount of change is more than one point. We got the *same result with our color combinations.* Of the cases where, in the original experiment, the effort to change the affective value of a color had resulted in a raising of its pleasantness by two points, this increased pleasantness appeared after the two months' interval in 17.2%; of the cases where pleasantness had been lowered two points, 7.6% were permanent; of the cases where pleasantness had been raised three points, 12.4% were permanent; of the cases where pleasantness had been lowered three points, 4.5% were permanent; of the cases where pleasantness had been raised four points, 10.5% were permanent; of the cases where pleasantness had been lowered four points, 10.7% were permanent; of the cases where pleasantness had been raised five points, 9% were permanent; of the cases where pleasantness had been lowered five points, 4.6% were permanent. If these percentages are averaged for the 'raising' and 'lowering' changes respectively, the 'raised' changes show an average of 11.2% of permanence, the 'lowered' changes 6.8%. The corresponding figures from the earlier investigation, with the single colors, were 11.1% and 5.9%.

We may next consider the methods by which the changes in pleasantness of the color combinations were effected, according to the introspective testimony of the observers.

In the case of the single colors, "by far the most frequently used method was the one which we have called 'imaginary context'. The color was thought of in an imaginary setting different from the real one." Special forms of imaginary context consisted in "imaging the color in combination with some other color," and "imagining the amount of the color to be increased." These methods we found to be used in the case of the color combinations, and in addition there appeared the method of imagining a change in the relative amounts of the two colors used in the combination. The method which in the former paper was called 'shift of attention' took on an altered form in these experiments with color combinations. Where the simple impression of a single color was used as the source of the affective reaction, attention could be shifted from a disagreeable to an agreeable aspect of the color, or *vice versa*, only by attending to some association which the color suggested from past experience. Where, on the other hand, the more complex impressions from color combinations were the source of the affective reaction, attention could be, and was, shifted from one color to the other, making the more or less agreeable color dominant in the com-

bination. In treating the results of the present series of experiments, with the color combinations as stimuli, we included cases where the colors suggested associations from past experience under the head of 'altered context', instead of under the head of 'shift of attention'.

The significant results which we have obtained in regard to the methods by which the affective values of the color combinations were changed, as compared with the methods by which the affective values of the single colors were changed, are as follows.

For both combinations and single colors, the occurrence of associated ideas is more likely to raise than to lower pleasantness. In the experiments with the single colors, where changes by this method were reckoned under 'shift of attention', "the average percentage for increasing pleasantness was 24.4; for decreasing pleasantness, 15.3." With the color combinations, where changes due to association were classed under the head of 'altered context', the average percentage for increasing pleasantness was 53.8, and that for decreasing pleasantness 27.1.

There is *less tendency* to alter affective reactions by *imagining the absolute amount (area) of the colors altered*, in the case of color combinations than in the case of single colors. With single colors, 4.2% of the changes were due to this method; with color combinations, 1.4%. It is probably harder to imagine changes in the absolute area of color combinations than in that of single colors.

There is *much less tendency* to alter affective reactions by *imagining another color added*, in the case of color combinations than in that of single colors. With the single colors as stimuli, 17.7% of the changes were due to this cause: with the color combinations, only 3%.

Shift of attention from one color to the other in the combination caused 16.9% of the changes where color combinations were used as stimuli.

Affective adaptation was *somewhat more influential in causing changes in affective reaction where color combinations were used as stimuli* than when single colors were used. With single colors, it was responsible for 2.2% of the changes; with color combinations, for 4.5%. The authors of the study in which single colors were used say: "Probably the slight influence of affective adaptation in these experiments is due to the mildness of the emotional reactions involved."

True compensation, the deliberate assumption of the opposite affective attitude ("I said to myself, 'Now like it!' and I did") *occurs oftener with the color combinations* than it did with the single colors, though it is still rare. It occurred in six tenths of one percent. where the single colors were used, and in 2.5% of the cases where the color combinations were used. The authors of the previous study say: "It is easy to conjecture that this method, so useful in ordinary life, would naturally play little part in conditions where the affective state is not only mild, but accompanied merely by simple motor expressions. One may assume hatred in order to counteract love, for example, because hatred may be expressed by a great variety of movements, by torrents of words, by forcible actions, and when these voluntary movements are set in operation, there is a fair chance that the deeper organic movements associated with them may come into play and the emotion really be transformed. But expressing one's like or dislike of a color is so mild and simple a motor process that its voluntary performance can have no very profound effect." Expressing one's like or dislike of a color combination is also a mild and simple proceeding, yet quite possibly not so mild and simple as that called forth by a single color; and this difference in complexity may be responsible for the greater use of compensation with the color combinations. The number of cases, however, is so small that the difference may be accidental.

REVIEWS OF BOOKS

Human Behavior, in its Relation to the Study of Educational, Social and Ethical Problems. By STEWART PATON. New York, Charles Scribner's Sons, 1921. Pp. 465. Price $6.00.

The need of a study of human behavior more inclusive than has been forthcoming from psychologists has often been felt by those who deal practically with human nature, and especially by the alienists. Definite beginnings of such a study have indeed been made, as, for example, by the psychoanalysts after their manner and by Dr. Adolf Meyer in the "Psychobiology" which he has been teaching for a number of years at the Phipps Clinic. Dr. Paton's book is a contribution from the point of view of the biologist and the physician to this same admirable and difficult undertaking. Its main thesis is that adult human behavior can be properly understood only when studied in all the light that can be shed upon it by the comparative study of behavior in less developed organisms—both those lower in the animal series and earlier in the human series, including even the embryo—and of the disordered behavior of the insane. The behaving individual must also be studied both as a unit, neither mind alone nor body alone, and in its dependence upon all its several systems—not alone upon the central nervous system, but upon the autonomic, the endocrine, the circulatory, the muscular, and the vegetative.

In supporting this thesis in detail Dr. Paton discusses the adjusting mechanisms (nervous and non-nervous), personality and its development, temperament, character and intelligence, the mechanisms of control, dispositions, habit formation, the involutionary processes of old age and the conflicts and dissociations of imperfectly organized personalities. Other chapters treat of the historical development of this general point of view, of the methods to be used in the study of personality, of education and of the broader benefits which may be hoped from a perfected science of human behavior. In its major outlines the book is excellent. Its standpoint is sound and the author's insistence upon it is timely; his account of present day knowledge of the biology of behavior is complete and authoritative; he points out many promising openings for research; his incisive criticism of current educational practice is deserved.

But the psychological reader, even though he be a sympathetic one, is apt, nevertheless, to lay the book down with something of disappointment. First because it demonstrates all too clearly that the study of human behavior, though it draws upon established sciences, has not itself as yet fully reached the scientific level. This appears not so much in the incompleteness of present information, which Dr. Paton notes at many points, as in what he himself says incidentally with reference to terminology and methods. On p. 50 he urges the retention of the word "consciousness" in spite of its manifold and recognized ambiguities. On p. 355 he notes that "as soon as we abandon the attempt to seek for rigid definitions we shall—as has often before been the case in the development of the study of human activities—find ourselves in a far better position to interpret the significance of processes which are now only partly understood." And again on p. 372 he warns the would-be student that the successful examiner of personality is "born not made" and that "one may acquire, by diligent practice and long experience, some considerable skill in exploring and exposing the basic influences which condition character, but there is a point in the analysis beyond which the examiner cannot go unless he himself possesses the peculiar adaptiveness and insight associated with a natural

aptitude for making personality studies,"—all of which is probably true, but could not be said truly of a study already upon its feet as a science. Perhaps, indeed, no science of human behavior is possible.

For this cause of disappointment the psychologist may well blame his own over-sanguine expectations, but for two others he may fairly hold the author to account. In the first place the work bears the marks of haste in preparation or at least of having missed a final revision. It is uneven in style; a paragraph here and there reads as if it had been incorporated without change from the author's notes of his reading and in consequence is difficult to understand without as full a knowledge of the original; others are clumsily worded and obscure without even this excuse. Superficial contradictions, too, occur here and there. We read, for example, on p. 81 that "there seems no evidence that warrants the attribution of any specific form of psychic activity to the cerebral cortex," but on p. 63 of "the higher complex faculties described as reason—a function of the cerebral cortex," and on p. 144 that "the higher cortical centers of the brain are those in which the mechanisms of self-consciousness are chiefly represented." On p. 147 we hear of "the vague self-consciousness which dawns at birth," but learn on p. 154 that "gradually . . . . as the muscular system falls more and more under the control of the brain and both the sensing activities and their coördinations become greater, there emerges the complex of responses which we recognize as the first indication of the dawn of self-consciousness." These are rather trivial matters perhaps, but obscurity and carelessness help neither the reader nor the cause which Dr. Paton has at heart.

That Dr. Paton's psychological terminology would have been reformed in a last blue-penciling is by no means sure, but it is a pity that he could not have had at the critical moment the aid and comfort of some competent colleague. He would have learned that no psychologist writes of "sensing . . . . ideas" (p. 118), or of a "sense of appreciation dependent upon the evaluation of muscular contractions" (p. 141) or of "a sense of credulity" (p. 327), and that no psychologist, except in joke, would give his endorsement to such a statement as that which is cited on p. 279, to wit, that "one-third of our mental make-up is instinct, one-third habit and one-third a process of becoming one or the other." Among the nearly 400 authors to whom Dr. Paton refers there are a goodly number of psychologists, but he has evidently proved immune to their manner of speech, if not also to their manner of thought.

When a science of human behavior comes, if it ever does, it will come as the joint work of the biologists and psychiatrists on one side and of psychologists and sociologists on the other, and each party will have to know well and give respectful attention to the work of the other. Dr. Paton presents us with an excellent account of the data which his side can now contribute. We trust that his acceptance of a place on the programme of the recent meeting of the American Psychological Association at Princeton argues an inclination on his part toward a better acquaintance with working psychologists and a more intimate knowledge of their science.

E. C. S.

Psychology: A Study of Mental Life. By ROBERT S. WOODWORTH. New York. Henry Holt & Co., 1921. Pp. x, 580.

In an easy and conversational style, Professor Woodworth presents in this book his idea of modern psychology, which, as he says in his opening sentence, "is an attempt to bring the methods of scientific investigation. . . . . to bear upon mental life and its problems." Abandoning the traditional isolation and independence of psychology as a separate science, he adopts the point of view that it is a department or branch of biology. He regards psychology as "the science of the conscious and

near-conscious activities of living individuals" (p. 17). The prototype of the conscious and near-conscious activities is the simple reaction, which is "a *response* to a *stimulus*" (p. 22). This schema of stimulus-response is of great systematic importance. It appears in the exposition of all the activities, the conscious and the near-conscious, the higher and the lower, the native and the acquired, and it forms the scaffolding of the entire work.

In the opening chapter, Woodworth describes the subject-matter, problem, and methods of psychology.

The subject-matter of psychology is the mental activities, which form a sub-class of the vital activities. The activities considered are those of individuals as distinct from those of groups and from those of single organs: a distinction which separates psychology from sociology on the one hand and from physiology on the other. The limiting adjective 'mental' is merely relative, for the near-conscious activities—those closely related to consciousness—belong properly to the subject-matter of psychology. Within these broad limitations the activities which psychology studies may be human or animal, adult or child, normal or abnormal.

The problem of psychology is threefold: to determine how individuals differ in their mental activities, how they resemble one another in their mental activities, and how the study of these differences and these likenesses may be put to practical ends.

The general methods of psychology are the experimental, comparative, genetic, and pathological. With every one of these two specific modes of approach may be followed: the introspective (the mode peculiar to the science of consciousness), and the objective (the mode peculiar to the science of behavior). Woodworth employs both.

With the field thus defined, "the next question is where to commence operations" (p. 21). The answer, of course, is "to start with the simplest sorts of mental performance, either with sensations, as do the introspective psychologists who think of sensations as the chief elements of which consciousness is composed, or with reflexes, as do the behaviorists who conceive of behavior as composed of these simple motor reactions" (p. 21). The cue is taken from the behaviorists "because the facts of motor reaction are more widely useful in our further studies than the facts of sensation, and because the facts of sensation fit better into the general scheme of reactions than the facts of reaction fit into any general scheme based on sensation" (p. 22). A further "advantage of basing our psychology on *reactions* is that it keeps us 'close to the ground', and prevents our discussions from sailing off into the clouds of picturesque but fanciful interpretation. Psychology is very apt to degenerate into a game of blowing bubbles, unless we pin ourselves down to hard-headed ways of thinking. The notion of a reaction is of great value here, just because it is so hard-headed and concrete" (p. 68).

The reaction is therefore accepted as the fundamental basis of psychology, and is defined as "a *response* to a *stimulus*." A stimulus is any force or agent that, acting upon the individual, releases energy stored in the organism; and a response in the simplest case is a muscular movement, in more complex cases any act of the individual organism: a feeling, sensing, doing, observing, knowing, inferring, etc.

Working from the simple to the complex, Woodworth in Chapter II considers the reflexes and other elementary forms of reaction, and then advances in Chapter III to the reactions of the higher levels. He argues that under his definition "there is no reason why we should not include a great variety of mental processes [sensations, perceptions, thoughts] under the general head of reaction" (p. 45).

In Chapter IV purposes, motives, interests, or tendencies (as they are more aptly called), which at first thought seem to transcend the 'stimulus-response' point of view, are reconciled to it. Woodworth finds that a pur-

pose is itself an inner response to some external stimulus, which persists for a time, and which acts in its turn as a central stimulus to further reactions.

With this "stock of methods and general concepts," Woodworth turns in Chapter V to the consideration of the case of democratic John Doe: which of his traits are native and which acquired? Proceeding upon the criterion of universality, that that trait which all individuals of the same descent show in common is native—unless evidence can be brought forward to the contrary (p. 98), Woodworth classifies the native traits as: reflex, instinct, emotion, feeling, sensation, attention, and intelligence. These traits he describes, so far as possible, from both the objective and the subjective points of view.

Reflex and instinct are described only from the objective side. The reflex is a motor or glandular response; the instinct is a motor or glandular tendency. Neither is conscious, but both are near-conscious in that they are somehow like the conscious.

Emotion is described from both points of view. On the objective side the emotion, which (as the inventory of the instincts and emotions in Chapter VIII shows) is closely bound up with instinct, is a neural response. It is the end-result of a number of internal and external preparatory acts of muscles, organs, and glands. On the subjective side it is closely bound up with impulse, with the conscious tendency of "wanting to do something." Considered apart from this tendency, however, emotion is a "conscious stir-up," a "feeling somehow," a "mass of sensations" aroused by objective bodily changes.

"Feeling is subjective and unanalyzed"; "it is simply the 'way you feel'" (p. 172). While conscious, it is not cognitive; for "as soon as you begin cognizing and say, 'I feel badly here or there, in this way or in that,' you know something about your subjective condition, but the feeling has evaporated for the instant." On the objective side "feeling is an impulse to 'stand pat' or to end the state;" it is, in other words, a specific neural tendency.

Sensation on the subjective side is bare conscious response. "The child does not learn to see or hear, though he learns the meaning of what he sees and hears. He gets sensation as soon as his senses are stimulated, but recognition of objects and facts comes with experience. Hold an orange before his open eyes and he sees, but the first time he doesn't see an orange. The adult sees an object, where the baby gets only sensation. 'Pure sensation,' free from all recognition, can scarcely occur except in the very young baby" (p. 187). On the objective side "sensation may be called the first response of the brain to the external stimulus." "Without the brain response, there is apparently no conscious sensation, so that the activity of the sense organ and sensory nerve is preliminary to the sensation proper." After describing the various sense organs and discussing the elementary sensations and their blends or compounds,—a discussion marked only by unqualified acceptance of the Ladd-Franklin theory of vision,—Woodworth turns to the consideration of adaptation, after-image, and contrast. This chapter on sensation, he tells us in the preface, "might perfectly well be omitted.....without appreciably disturbing the continuity of the rest."

"Attention is preparatory, selective, mobile, highly conscious." "To attend to a thing is to be keenly conscious of that thing, it is to respond to that thing and disregard other things, and it is to expect something more from that thing" (p. 244). Attention is a complex response. "Its natural stimulus is anything novel or sudden, its 'emotional state' is curiosity or expectancy, and its instinctive reaction consists of exploratory movements, its inherent impulse is to explore, examine, or await."

On the subjective side attention is highly conscious. "One of the surest of all introspective observations is that we are more conscious of

that to which we are attending than of anything else." On the objective side attention is a neural and motor reaction: neural, in so far as it is a mental activity; for degree of consciousness tallies, not with intensity of sensation or energy of muscular action, but with degree of mental activity; and motor, in so far as the movements that occur in attending to an object are such as to bring the sense-organs to bear on that object as efficiently as possible.

Intelligence comprises the organism's innate limitations and susceptibilities of reaction. On the subjective side intelligence is like reflex and instinct, *i. e.*, it is near-conscious. On the objective side it resembles instinct in that it is a native tendency; but instinct consists in ready-made native reaction-tendencies, whereas the intelligence of an individual at any age depends on what he has previously learned. It might appear from this statement that intelligence is not a native but an acquired trait; but, in fact, what the individual learns depends upon his retentivity, his responsiveness to relationships, his persistence, his submissiveness, his curiosity, and his special aptitudes.

The acquired reactions and tendencies to react—all knowledge, the whole stock of ideas and of motor skill, and certain motives and likes and dislikes—are modifications of the native forms just mentioned. In the next four chapters the processes of learning and acquiring these modifications are described. The first is devoted to the acquiring of motor habits and skill; the second, to memory; the third, to acquired mental reactions; and the fourth is given to association, to a consideration of the general laws of exercise and of combination which hold sway in the whole field of acquisition of reactions.

At this point the decision is reached that John Doe's "behavior is primarily instinctive or native, but that new attachments of stimulus and response, and new combinations of responses, acquired in the process of learning, have furnished him with such an assortment of habits of all sorts that we can scarcely identify any longer the native reactions out of which his whole behavior is built." Henceforth we must keep him under surveillance in order to see what use he makes of this vast stock of native and acquired reactions, how he behaves from day to day, and how he meets the exigencies of life (p. 419). Study reveals that "his life is a voyage of discovery and at the same time a career of invention" (p. 421).

The culmination of the process of discovery is perception. On the subjective side "it consists in responding to a stimulus by knowing some fact indicated by it either directly or indirectly" (p. 422). Sensation gives us the sign of some fact; perception, the meaning of the sign. On the objective side perception is a secondary response to a physical stimulus, being properly a direct response to the sensation. "The chain of events is: Stimulus, response of the sense organ and sensory nerve, first cortical response which is sensation, second cortical response which is perception" (p. 423). It is only, however, the simplest perception which is thus singly determined; ordinarily it takes a collection of stimuli to arouse a perception. This collection is at the same time a selection (under the laws of attention and association) from the whole mass of sensory stimuli acting at any moment on the individual. "Perception is at once an isolating and combining response" (p. 431). Reason is the counterpart of perception; "indeed in discussing reason we are still on the topic of perception." The reasoner is an explorer, and the goal of his exploration is the perception of some fact previously unknown to him. Two facts are present as stimuli, and the response, which on the subjective side is called inference, consists in perceiving a third fact that is implied in the two stimulus facts. "Inference, typically, is a response to two facts, and the response consists in perceiving a third fact that is bound up in the other two." On the objective side reasoning is the same as perception, a neural response of the cortical regions adjacent to the sensory areas.

From exploration and discovery, which are involved in perception and reason, we turn to manipulation and invention, which are involved in imagination. The stimulus consists of facts, either perceived at the moment or recalled from past perception, that are now freshly related or combined. The response may be divided into two phases: preliminary, receiving a combination of stimuli; and final, responding to the combination. Typically, the preliminary stage consists in the recall of facts previously perceived. The final stage is invention, which consists in a response to the novel combination of facts.

Will and Personality, the subjects of the closing chapters, are not psychological terms in so far as they are not special kinds of responses. Will refers to certain relationships in which a response may stand to other responses; personality, to the array of native and acquired traits. Under the heading 'Will' Woodworth discusses the various kinds of action and the practical applications of the subject, "how to get action either from yourself or from others." Under 'Personality' he discusses the factors involved, the development and expansion of the self, and the unconscious mind. In his consideration of the unconscious, he severely criticises the concepts and tenets of Freud and of the psychoanalytical school.

We have here an empirical biological system which has been cast in the mould of "stimulus-response," a mould which even cursory study reveals as inadequate. The concept is teleological throughout, and the logical consequences of interactionism can not be escaped.

Few definitions are attempted. Woodworth is satisfied for the most part to rely upon the common-sense appraisement of his terms. Where this seems inadequate, and he does attempt definition, the formulas are for the most part vague and uncertain. For example, the definition of reaction, the unique and fundamental concept of the system, is "a *response* to a *stimulus*." Yet nowhere do we find an exact definition of either of these terms. A stimulus is "any force or agent that acting upon the individual arouses a response;" but what, then, is a force or agent? is it physical or mental or physiological? and how does the undefined force or agent act, and what does it act upon? Woodworth replies that it acts upon the individual, but again he nowhere tells us what he means by an individual. What does the force do to this enigmatical individual? We are told that it "arouses a response." And response is described as any act of the individual organism aroused by a stimulus. Tautology, pure and simple! One member is defined in terms of the other. When we turn to the acts themselves, we find that acts of the muscles, glands, organs, end-organs, nerves, sensory centers, cortex, as well as stir-ups, wanting-to-do-something, feeling, sensing, highly conscious consciousnesses, observing, doing, knowing, inferring, inventing and modifying appear on the scene. But these activities belong to very different universes, and can be brought together under the concept of reaction only because of the looseness of the terms employed.

Psychology does not, however, include all the activities that can be grouped under the concept of stimulus-response, but only those that are "conscious or near-conscious," only those that come from "the organism or individual as a whole." Upon these principles, Woodworth excludes the activities of digestion, of the circulation, of the liver, etc. The limitation of subject-matter would be more comprehensible if "conscious" and "near-conscious" and "organism as a whole" were unequivocally defined. They are not; and we find that the author's exposition but adds to our perplexity. On p. 73 he illustrates the organic level of purposive behavior by reference to the stimulation of a single muscle, which by his own criteria must be physiological! Again it is difficult to see, on the basis of relation to consciousness, why he includes reflex, instinct and intelligence and excludes digestion, circulation and breathing. On the basis of

extent of activity, whether of a single organ or of the whole individual, the case is even more puzzling. The activity of the circulatory system, which extends throughout the entire body, is excluded, whereas the isolated pupillary reflex is included. It is also not easy to see why Woodworth includes emotion and attention among native traits. Emotion, he says, "consists wholly of the sensations of bodily changes." Why, then, is it listed as a separate trait? Why is it not included in the chapter on sensation and discussed as a blend? Elsewhere, we read that "all the emotions belong under the general heading of the feelings." Attention from the objective point of view gives us nothing new; it practically amounts to emotion, instinct and impulse. From the subjective point of view, however, we find that "we are more conscious of that to which we are attending than of anything else;" attention is a high degree of consciousness. Since degree of consciousness tallies, not with intensity of sensation or energy of muscular action, but with degree of mental activity (p. 266); and since mental activity is defined as conscious or near-conscious activity; it follows that attention is a high degree of consciousness which goes with a high degree of conscious or near-conscious activity.

The discussion of attention brings up the question of degree of consciousness. What does this expression mean? How can there be, for instance, degrees of consciousness in the field of sensation? This trait, be it remembered, is not cognitive. When we pass to the more complex levels, awareness and cognition appear, and degrees of consciousness find ready application. Still, even at the cognitive level, the concept is not without its pitfalls; it implies a permanent mind, a knower, and carries us back to the old 'self-activity' psychology. This implication is also present in Woodworth's concept of tendency. His exposition is straightforward and clear in the explanation of tendencies and the treatment of native traits; but in his discussion of the acquired traits and of the modifications which follow the laws of exercise and combination the implication of a permanent mind is very apparent. For example: how can use or exercise modify a native trait? Modification is explainable only by the tacit assumption of the middle term, the tendency, which is effective in both directions: toward the stimulus, in the substitution and detachment of the original stimulus; toward the response, in the substitution and combination of responses.

The style of the book is colloquial, facetious, and even slangy, as some of the excerpts already quoted show, and as the following remarks will further illustrate: "The dog passed another on the way without so much as saying 'How d'ye do?'"; "We had better fetch that law out again and put it in good repair and see whether it is adequate for the job that we now have on hand;" "Now bring in our trusty law of exercise;" "The law of combination seems to fill the bill very well;" "Errors of any kind are meat to the psychologists;" "Not that Freud would get our OK." It is at least doubtful whether this innovation is of advantage to a scientific text-book.

K. M. D.

Die Grundlagen der psychischen Entwicklung. Eine Einführung in die Kinderpsychologie. By K. KOFFKA. Osterwieck am Harz. 1921. Pp. viii+278.

This book is more than a restatement of facts and inferences regarding mental development and the psychology of childhood; it is a reinterpretation of the genesis of mind according to certain principles of mental structure which have grown out of the recent experimental work on *perception* undertaken by Köhler, Wertheimer, Koffka, and their collaborators. The new point of view is radical in its abandonment of the conscious element as a unit of structure, for with this go also the law of association,

as commonly understood, and likewise the well-worn mechanistic conception of interconnecting neural pathways. In place of the older theory of mind as originally a chaos of discrete elements which must be associated together by frequent repetition in order that certain 'bonds' of connection may be established as habits, the new structural psychology finds a 'closed system' already formulated as an original phenomenal datum. Corresponding to this is a 'closed system' on the physical side which replaces the discrete stimulus; while mediating between the two are the functional uniformities of the organism in its biologically adaptive processes.

From this point of view the mechanistic interpretations of behavior advanced by Thorndike and Watson come in for detailed criticism. Over against the experiments of the American students of animal behavior are placed those recently carried out by Wolfgang Köhler at the experimental station established by the Prussian Academy of Science at Teneriffe. As an indication of the difference, both in method and results, which arises from so radical a difference in the point of view from which the problem of behavior is attacked, we may state the case briefly as Koffka presents it.

Thorndike, in his famous puzzle-box experiments, confronts the animal with a task which can be solved only by chance. The appropriate response by which release from the box is obtained is not one which the animal could readily understand, even if it had the capacity of understanding. Hence the trial-and-error method employed is both tedious and wasteful. That the animal does, nevertheless, succeed eventually in mastering the situation is not explained by repetition alone, as Thorndike admits; nor is it explained by the satisfaction that attends an effective performance, since neither a preformed neural readiness to do the act in question nor a pleasurable nuance attaching to this fortuitous activity can be assumed. The animal learns here, as elsewhere, according to Koffka, by the formation of a functional structure which includes in its continuous course the 'situation' of hunger and irritability upon confinement, the selective manipulatory act of release, and the subsequent enjoyment of freedom and food. But the conditions under which this complex series of states and events is formed are the worst possible in which to reveal inventiveness or intelligence. Hence the act is but slowly acquired, and readily forgotten, because the important factors in the total structure are motor rhythms which do not naturally find a place in the original impulsive situation. Yet even here the type of activity involved in the release has an important bearing upon the efficiency of the animal's learning. When Thorndike taught his cat to lick itself before he would open the cage and release it, he found that the act in question rapidly degenerated into the merest rudimentary gesture; and if not then given its freedom the cat failed to repeat the performance immediately as it would always do when its act had a direct bearing upon the mode of release. Thorndike was unable to explain this fact, but Köhler's observations lead him to conclude that the behavior of the animal is always typically different when the act it is called upon to perform is, from its point of view, senseless. An efficient performance in solving a problem always involves some 'insight' on the part of the animal, that is, the means taken to achieve the end always indicate an inner structural connection.

Thus Köhler in his experiments with chimpanzees and hens always planned a situation where insight was possible, leaving the results to determine whether it was present or not. In general the arrangements in Köhler's tests were such that, in order to secure a reward, the animal must discover an indirect means by the use of a tool or by overcoming some hindrance in its way. Thus a basket of fruit placed outside of the ape's reach could be secured by pulling on a string attached to the basket, by poking it forward with a stick, or by mounting upon a box which the ape must first place under it. These tasks were not always easy to perform, but

the achievement, after many vain attempts interspersed with periods of rest, was always a sudden and immediate reaction in which the means employed in attaining the end had all the characteristics of an intelligent discovery. One of the most interesting of these discoveries was the use made of two pieces of bamboo by putting the smaller into the end of the larger to give a needed extension. The ape had previously poked out one stick by means of the other until it touched the basket, but it was only in what appeared to be an idle moment of play that the discovery of fitting the smaller into the larger stick was made. At once the animal went for the basket with the now lengthened stick, and though the sticks fell apart because they had not been well put together, the ape was not deterred in its purpose, but refitted them again, and fetched in the fruit.

That structural formulations are original phenomena of the mind, and not a product of previous learning, is indicated by the experiments with hens, a species not precisely noted for intelligence. Having found that hens can discriminate light and dark papers, these were placed on food boxes and the hen trained to select the box with the darker label. In the course of the experiment care was taken to alter the position and also the papers, so that the cue should be given by the specific brightness and not by any other factors. After training, 'critical' tests were made in which a lighter or a darker color than either of those in the training series was exposed along with the 'positive' color which the hen had been taught to select, or the 'negative' color which it had been taught to reject. If behavior is originally determined by a discrete stimulus we should expect the hen always to select the positive color, whenever present, and likewise always to reject the negative color. But this was not the case; if the hen had been taught to select the darker of two colors, it continued to select the darker, even when the box in question had been the 'negative' box in the training series. Likewise it rejected what had been the 'positive' box in favor of one whose color label was still darker.

From such results as these Koffka elaborates a theory of structural phenomena upon the basis of which he proceeds to give a reinterpretation of mental and bodily development, the nature of reflexive and instinctive activity, and the mode of learning. The genesis of a phenomenal structure is the appearance of a *quality* limited and somewhat definite on a background which is both vague and indefinite. These are the most primitive phenomena of perception in which every member of the structure carries all the other members along with it. Thus, the discovery of any particular member, as such, is the creation of a new structure, which has not previously existed. Whatever arises in consciousness as a structure is something to which the organism reacts, being conditioned not only by the corresponding structures involved in the physical impression, but likewise by biological needs and impulses of behavior. Thus 'friendliness' and 'unfriendliness' are more primitive structures than a *blue spot*, and in the original structures the affective elements are in no wise distinct from the perceptual. The assumption that a sensation is determined for all time by its stimulus must be given over, for a sensation is only a highly elaborate and refined structure, entirely a product of analysis, and in no sense an original datum of mind. Thus, for example, the color discrimination of infants, to which the author gives detailed consideration, must be reinterpreted in terms of structures, light and dark, 'warm' and 'cold', colored and uncolored, in place of the discrete sensory elements which have hitherto been assumed to indicate the presence or absence of color sensitivity.

Transfer of training is readily understood as an acquisition of structures; for within a broader structure a partial structure of similar form may find facilitation of expression, whereas Thorndike's doctrine of 'identical elements' makes no such provision for flexibility of application. Again, learning to read by sight through sheer repetition is futile, because one never learns anything unless opportunity is given for recitation in

which the material can be worked over into a structural form. Learning is never a mere connection of impressions or acts, but always a certain *way* of acting. But, a certain way of acting having been learned, quite different materials both of perception and of response may be suited to the performance; for it is not the materials, either as sensory ingredients or as specific muscular reactions, which constitute the phenomenal structure that has been learned, but something quite different, conditioned by the functional uniformity of the organism in its biological processes.

Here, however, the author leaves us in doubt, for apparently he has no psychological doctrine of integration by means of which the analytic data of the phenomena of perception are shown to constitute these mental structures. If the same structure may arise under totally different conditions of stimulation and persist through various muscular adjustments of response, is there no strictly phenomenal pattern by which the identity of the structure can be gauged? It would seem that Koffka regards this identity of structure as sufficiently defined in terms of its biological function; but though he attempts to overcome the opposition of mechanism and vitalism as alternate explanations, by an interpretation which is neither the one nor the other, he is not altogether successful in making clear his emancipation from teleology. Much attention is given to the variety of structures, primitive and acquired, and also to the genesis of series and groups in perception and in movement, but one is troubled by the lack of an unequivocal determination within the phenomenal realm of consciousness itself.

In considering the tests of Köhler on apes and hens with respect to the apparent size of objects and the surface-color of labels, one might suppose from the results obtained that within the structural range of an ape's view there is no phenomenal difference in the perceived size of an object as it recedes into distance, and likewise that the surface-color of a neutral grey remains phenomenally constant even when its comparative brightness has been reversed with reference to the 'negative' color of the training series. The facts as indicated in Köhler's careful tests are unimpeachable, yet no attempt seems to be made to account for them in phenomenal terms. A similar criticism has been made of Wertheimer's 'phi phenomenon,' as the essential structure of visual movement; but Dimmick found conscious data for the 'phi phenomenon' as a grey flash integrating with an attribute of duration.[1]

Even if we are now led to relinquish elemental sensations and their association as the groundwork of psychology, must we turn to biology, with its teleological or mechanistic implications, for the interpretation of every mental structure that a concrete act of behavior may imply? Is it not rather the problem of psychology to investigate these mental structures as integrations of qualities involved in their membership, in order that the gross nature of the structured *quale* may be reduced to attributive aspects such as qualitative modality, intensity, duration, spread, etc., each one of which can be controlled by a corresponding variation of the stimulus? One has an uneasy feeling that these new phenomenologists of mental structure are too ready to posit the phenomenal side of behavior as unique data which cannot be more closely defined. Yet a structure whose members are incapable of definition is hardly a scientific datum, and if every definition must be functional, that is, organic, psychology is still thrown back upon the tender mercies of biology, just as surely as the behaviorist argues that it must be. Even though the physical universe itself, which supplies the 'situations' for behavior, is rightly conceived as an elaborate interconnection of structures to which no mechanistic interpretation of accretion and summation can ever do justice, yet the uniformities of the physical universe do submit to definition. Why not also the corresponding uniformities of the mental structure, and, indeed, in much the same way?

[1]Cf. this JOURNAL, xxxi., 1920, p. 317 ff.

These are but some of the questions which come to one's mind after attempting to digest this somewhat bewildering review of the subtleties of mental development and child-life that Koffka has managed to compress within the limits of a small book. We have neglected to trace the outline of his treatise, and have omitted many illuminating inferences which carry us far beyond the crude and stodgy interpretations which are still current in present-day American pedagogy. But it seemed more important, in attempting to bring this very significant point of view to the attention of American readers, to devote our space to the new theory and certain of its implications, rather than to review the book with reference to its specific content. We may venture to hope that the volume will be widely read by educational psychologists, because it is filled with nuts for the behaviorist to crack, and if not all are ready to throw over their pet theories of applied psychology in favor of the one here proposed, no one can fail to benefit from the redefinition of his conceptions which the reading of this book will force upon him.

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A Treatise on Probability. By JOHN MAYNARD KEYNES. London, 1921. Pp. xi + 466. Price 18s.

The author of the *Economic Consequences of the Peace* here sets forth a logic of probability, an attempt to treat in comprehensive and systematic fashion the problems of the philosophy of induction with the related general principles of mathematical probability and statistical inference. The work belongs to the course of thought initiated by Leibniz, left undeveloped for a time, brought again into prominence by Hume and Mill, and revivified and applied to the concrete by Laplace and Jevons and Venn. The treatise itself was begun as a fellowship dissertation at Cambridge under the influence of W. E. Johnson, G. E. Moore, and Bertrand Russell, to whom it owes much both for problem and method. After the interruption due to war work, it is now modestly presented "for criticism and enlargement at the hands of others." It intends to supplant by constructive theory some of the negative criticism contained in the chapters on induction in our present-day texts on logic, but it offers also a wealth of critical material to mathematicians who are willing to be concerned with the presuppositions of the theory of probability, as well as a variety of suggestion and caution to all who make use of statistical methods in seeking scientific conclusions.

The book is divided into five parts, with an index, and a selected and briefly annotated bibliography of 25 pages.

Part I gives the general epistemological setting. Probability is defined in its widest sense as a *relation* between propositions (premises) which are derived by direct knowledge, and other propositions (conclusions) which are derived from these indirectly by argument (inference). If not completely implied in and deducible from the data (premises) themselves, all conclusions thus have only a certain probability, and all true induction is effected by the application of a general theory of probability.

Probability, being itself a relation, is always relative to the data upon which it is based. A given conclusion may be probable on one set of data, and improbable on another set. Independent certainty, therefore, can be regarded only as the limit of all possible probability relations, based upon infinite (and therefore practically unattainable) data.

Keynes holds that probabilities, thus generally defined, are not always comparable, even theoretically. Expressed metaphorically, the "path" from data to conclusion is not always straight, and probabilities lying on two different paths may belong to different and incomparable orders. The measurement and mathematical comparison of two probabilities are

possible only when both lie in the same path. This occurs only when the conclusion is one of several exhaustive, exclusive, and equiprobable alternatives. Theoretically such a conclusion exists only for the problems of predicting tosses of a coin, balls drawn from a bag, and the like. The law of non-sufficient reason and the "frequency" theory of probability based upon it are applicable in such cases, but their application to apparently similar practical problems can be made only with reservation and great circumspection. In thus extending their application, the determination of the relevance of data to conclusions is critical. Nevertheless, at least in concrete practical problems where conditions are complex, our judgments of relevance must depend not upon rules, but upon direct insight.

Common uncritical acceptance of the frequency theory has tended to obscure the distinction between the probability and the "weight" of an argument, although it is clear that added evidence, while always increasing weight, may increase, leave unchanged, or actually decrease the probability of a conclusion. The common reliance upon the "probable error," as a measure of weight, is therefore justified only to the extent that further data are more likely to include more relevant and significant data. The probable error, as a partial description of observed facts, must not be confused with its use as an indication of the precision of a generalization regarding all (both observed and not observed) facts of the kind in question.

Part II restates the fundamental concepts and definitions of Part I in terms of symbolic logic. Thus, a/h represents the probability of conclusion a derived from premises h; $a/h=1$ represents certainty; $a/h=0$ represents impossibility, etc. From such simple definitions and axioms, the author develops the "laws of thought" or "necessary inference" (contradiction, excluded middle, etc.) and the theorems of "probable inference" (addition and multiplication of probabilities, inverse probability, etc.)

The remainder of Part II deals with the application of these theorems to various problems. First comes a treatment of the theoretical probability of testimony and the credibility of witnesses. Psychologists and especially those concerned with statistics and with theory of psychophysical method will find a wealth of new and particularly interesting material in Keynes' discussion of the assumptions ("laws of error") which are logically implied in our determinations of the most probable value of variable measurements by the method of least squares, and in our common use of the various averages, the median, etc., as representative values.

Part III contains a discussion of the assumptions which underlie induction, and a logical analysis of inductive generalization. Induction, in its most general form, consists in the observation of a limited number of things, all of which are found to have certain common and therefore essential properties (a known positive analogy), but some of which also are found to have, and others to lack, certain irrelevant properties (a known negative analogy). If we assume that the properties of natural things actually occur in finite "bundles", or are the result of a finite number of "generators," then knowledge of the essential nature of a thing can be increased by seeking and finding additional cases in which new and inessential properties appear. Induction, that is to say, proceeds by increasing the negative analogy, and thus more and more closely limiting the actually essential properties to those of the known positive analogy. Mere multiplication of instances as such would be logically valueless except for the *probability* that the new instances will, as a matter of fact, differ from those already examined in points of unknown but actual positive analogy.

Part IV begins with a discussion of "objective chance" and "randomness." The usual definitions imply the frequency-theory of probability. The author, therefore, redefines the concepts in terms of the general theory previously outlined.

Objective chance does not mean lack of determination,nor does it necessarily indicate a small probability of the occurrence of any given outcome. It exists when we suppose that no increase in our knowledge of the laws of nature and no *practicable* increase in our knowledge of conditions and principles or relevant causal laws will enable us to form more probable conclusions. Random selection exists when, in choosing a member from a group or class, we have no *a priori* warrant for supposing that we shall obtain any one particular member rather than any other, or when such knowledge as we have regarding the particular member obtained is irrelevant to the question whether or not this member actually possesses the characteristic under examination.

The definitions thus arrived at are then applied to a variety of problems: to the question of randomness in the distribution of angular inclinations of the orbits of planets, of random causes for the existence of binary stars, and in the existence of star drifts; to the questions of final causes and argument from design and to the problems of psychical research, etc. Finally comes a discussion of the application of probability to conduct. Here such questions as those of "moral risk" and the "Petersburg paradox" are treated in considerable detail.

Part V is a critical study of the foundations of statistical inference. The first chapter brings out briefly but emphatically the distinction between the purely *descriptive* use of statistics as applied to observed instances, and the far more difficult and uncertain use of statistical methods as a basis of inductive *generalization*. The following chapter gives briefly the historical setting of modern statistics, and deals chiefly with the "law of great numbers" as developed by the theoretical work of Bernoulli and Poisson and supported by the investigations of Quetelet. A great deal of later unjustified application of these principles and theorems, and of the modern preoccupation with the mathematics rather than with the logic of statistics, is to be attributed to the insufficiently critical attitude, the too general claims, and the sometimes unguarded language of these earlier statisticians.

Keynes then considers the conditions which must exist if Bernoulli's and similar theorems are to hold for various theoretical and practical cases. Bernoulli's theorem, for example, is rigorously applicable only if a knowledge of what occurs in early observations will not affect the probability of what will occur in later trials; and, secondly, if these probabilities are all equal among themselves. It can be applied for prediction in 1000 tosses of a coin only if our initial assurance as to the trueness of the coin and the conditions of tossing is so great that 999 "heads" in succession would not alter our half expectation of "tails" on the 1000th toss. "It is, in fact, difficult to give a concrete instance of a case in which the conditions for its application are completely fulfilled." This point is exemplified by an account of the attempts to verify the theorem *a posteriori* by actual coin tossing, dice throwing, lotteries, and roulette. Poisson's theorem accepts the second assumption but not the first, and the still further generalized forms of the theory due to Pearson, Czuber, Tchebycheff, and Simmons, though useful for particular instances, get us really little further in the general treatment of concrete cases.

The author next discusses the problem of the determination of general probabilities from numerical frequencies actually discovered for a group of instances of apparently similar character. He here severely criticizes the lack of logic involved in Laplace's law of succession and shows the absurdities to which its application may lead. The inversion of Bernoulli's theorem is held to be rigorously applicable only if we know that our original data are a true random sample. This knowledge, as already pointed out, is in most concrete cases practically impossible. [Psychologists who find a difference between the means of two *apparently* (but not *certainly*) unselected groups ought not to be surprised if on the next trial with two

apparently similar groups the direction of difference is reversed.] Numbers and mathematical treatment as such can never lead us to truth, apart from consideration of the methods and conditions and more general inductive procedures which we use in obtaining the numerical results. The beginnings of a truly critical work in this connection have been made by Lexis and von Bortkiewicz, a brief account of whose methods concludes the treatise.

It is easy to say in conclusion that logician, mathematician, and man of science owe a debt of gratitude to the author of the treatise for making a first truly comprehensive and critical study of questions which are of fundamental significance to all three disciplines. Not all logicians, of course, will agree that the distinction between knowledge gained by "direct" perception and that gained by argument is logically fundamental. Before we can apply the author's principles of induction to psychical research, for instance, we must have a theory of perception which will enable us to say more definitely whether or not we can directly perceive "spirits", a question which the author's system leaves open. Detailed and critical evaluation of the treatise, however, must be left to those more competent than the present reviewer.

WILLIAM S. FOSTER

University of Minnesota

Education and World Citizenship: An Essay towards a Science of Education. By JAMES CLERK MAXWELL GARNETT. Cambridge University Press, London, 1921. Pp. 515.

Any serious attempt on the part of an English educator to replace the traditional set of mind toward an art of education by a scientific attitude is worthy of notice. When an educator of the prominence of Maxwell Garnett (General Secretary of the League of Nations Union, and Dean of the Faculty of Technology in the Victoria University of Manchester) gives up all his spare time for eight years to the preparation of so pretentious a volume, certainly it is worth more than passing mention. To the Englishman, the book will doubtless mark a significant step toward the recognition of psychology as related to education. To the American, it indicates the systematic and cautious method by which the educators of the mother country are testing materials which, for some years, have been accepted in this country as basic. The book also shows something of the present state of mind of the typical English educator of the more advanced school.

Perhaps the best way in which to contrast the English and the American point of view is to give, without comments, the principal sources of the author's information, and the conclusions he has reached. The book is in three parts, each one of which will be briefly treated.

Book I gives three chapters to a consideration of the aims of education in the past, with a statement of the present situation. Rather startling is the statement that "the most easily observed characteristic of English education at the present time is perhaps its aimlessness." Accordingly, the author discusses a basis for determining a suitable aim toward which a science of education should be directed; Professor John Adams' conclusion that self-realization and a many-sided interest cover the whole field of educational objectives especially appeals to him, and so he finally concludes that the first aim of education during adolescence and maturity must be to build up a "single wide interest."

In Book II (16 chapters) "some of the conceptions of physiological psychology are employed in the attempt to analyse the foundations of character and their effect upon behavior." Rejecting a behavioristic view, and the doctrine of psychophysical parallelism, the author assumes "what Dr. McDougall calls the 'old common-sense view' that psychophysical interaction does in fact take place." Accordingly, in his psychological

presentation, he follows James and McDougall, except where the work of Spearman, Pearson, Hart, Cyril Burt and Edward Webb seems to give him experimental data which amplify and verify otherwise debatable conclusions.

As a result of this discussion, five "Laws of Thought" are enunciated. They are:

1. To every psychosis there corresponds a neurosis.
2. Excitement in the nervous arc tends to spread to every other arc that is connected with the first through synapses, the insulation of which the excitement in question is intense enough to overcome.
3. Any nervous arc of the higher level, if intensely excited relatively to other higher level arcs, tends to drain the impulses from those other arcs.
4. Will, measured by the general factor, "g", can reinforce the excitement in any excited system of higher level arcs; and so may cause that system to drain the excitement from all other active arcs of the higher level.
5. Action is the normal end of every train of thought.

Having arrived at these laws, and having noted that the first four laws show that a man's thought is determined, apart from incoming sense impressions, by his neurography and his will, it follows that, given a man's environment to which these incoming sense-impressions are due, his reaction will be determined when his neurography and his will are determinately known. "At least, we have no evidence of any other factors, and therefore do well to accept this view as the simplest possible hypothesis that fits all the known facts." A strong character is then made up of a neurography in the form defined as a single wide interest-system, and a strong will that cooperates with the single wide interest in guiding thought and conduct. Any one whose character is of this kind will possess an outlook on life which is something more than a philosophy, for it will show everything focussed in a supreme and dominant purpose. This purpose introduces deep emotional elements into his philosophy and transforms it into a religion, along with which he should have faith and hope.....To achieve correspondence between the central elements of one's neurography and the central essence of the endarchy of science is the most important step, on the neurographic side, towards the formation of character. One may achieve this either by accepting, provisionally, prevailing opinions, or by seeking an inspiration on one's own account. In either case, one must proceed to act on one's provisional hypothesis with a view to its verification. All conditions are satisfied by the fundamental Christian hypothesis: that God is the center of the universe, the central fact of the endarchy of science; that knowledge of God begins by faith; that hope of eternal life belongs to people who seek to know God; that brotherly love is of the very essence of God; and that all human beings are in peculiarly close relation to God. Thus, in a maximally progressive community, the common supreme purpose must be the Christian character just defined. The aim of education, the world over, follows at once: to form Christian characters, with all the manifold outward differences that are necessary if their several owners are to cooperate effectively for the fulfillment of their common supreme purpose.

Book III (7 chapters) describes a system of education to realize this aim, especially applicable to the situation in England, and sets forth plans for bringing her educational system into harmony with this aim within the next ten years. The problem is dependent primarily on knowing what each person's occupation is going to be. So it is necessary to investigate the qualities, especially the kind of "single wide interest", and the degree of "general ability or g", required by those who are to occupy the various positions in industry, commerce, and other essential departments of English life, and afterwards to indicate a means of developing the required qualities in a sufficient number of persons selected on account of their in-

nate aptitudes for each different kind of work. This selection must be made irrespective of the young peoples' place of residence and of their private financial circumstances....."We should neither ignore the value of education altogether, nor attempt to provide all men and women, whatever their ability or inclination, with identical education, but rather bring every kind of education within the reach of all citizens whose educational promise is sufficient to justify their selection to receive, if necessary at the public expense, that type of education, which, having regard to their ability and inclination, will best fit them to serve their fellows and to find their own happiness in that service." The classification of various kinds of public service is to be: (*a*) leaders in thought and action; (*b*) managers, officials, and others of intermediate rank; (*c*) craftsmen, skilled tradesmen, and leading hands; and (*d*) laborers, repetition workers, and other unskilled persons without specific training. In order to meet the demands of training for these various classes, attention should be paid to the application of the principles already laid down to methods of instruction and to types of schools. Both of these factors are touched upon at greater length than would be expected in a volume of this scope. The plan of schools includes ample provision for elementary, secondary, technical, university, graduate, and research institutions, and stresses particularly the need of part-time institutions of each grade—junior part-time, senior part-time, intermediate, advanced, and university part-time schools and classes. Ample provision is indicated for transfer from any one type of institution to another, when the right sort of ability is developed. In order to facilitate the universal opportunity, an elaborate national scholarship system is suggested, to cover every sort of training.

Finally, the volume closes with stress upon the supreme importance of training, appointing, and retaining teachers of the right kind: "in short, a perfect system of education requires, above all, perfect teachers; and perfect men and women, whatever their walk in life,—be it teaching or any other,—require a perfect education, an education that achieves its aim and so forms Christian characters."

One cannot imagine a psychologist reading Book II without reacting vigorously against certain conclusions there drawn; and one is certainly impressed no more by the matter included than by certain notable omissions. Yet the final impression is that an important advance has been made toward the end the author has had in mind, namely, the recognition in England of the applications of science to education. To the American educator, as well, there is much, especially in Book III, which is worthy of close attention.

R. H. JORDAN

Cornell University

PSYCHOLOGICAL PERIODICALS

Zeits. f. Psychologie. Bd. lxxviii., Heft 1 u. 2. E. R. JAENSCH. 'Grundfragen der Akustik und Tonpsychologie:' H. Lachmund. 'ii. Vokal und Ton.' [Experiments with an improved form of Jaensch's apparatus show that pitch is most certainly eliminated and vocality induced if the 'disturbing factor' is not wholly irregular but has a certain periodicity; the best vowels appear with periodic variation both of wavelength and of amplitude. The quality of the vowel depends on the average rate of vibration; 450 is characteristic of O_1 about 930 of A. Periodicity in the complex wave-form may set up a voice-tone (*Stimmton*), which ousts the (higher) average-frequency tone and carries the vocal quality. —The success of Helmholtz' synthetic procedure depends mainly upon the intensive ratio of the component tones. Its results are in accord with Jaensch's theory, since it provides for a 'disturbing factor' (the higher tone) and for a voice-tone.] H. Lachmund. 'iii. Ueber die Abhängigkeit der scheinbaren Schallstärke von der subjektiven Lokalisation der Schallquelle, ein Analogon zu den sog. zentralen Faktoren des Farbensehens.' [A source of sound is placed to right or left of the median plane, and the sound is so led to the two ears that the intensity of the uniaural impressions is the same. With binaural hearing, the source is localised to right or left, as the case may be, and the sound is far louder in the 'nearer' ear. The phenomenon is analogous to the 'memory color.'] E. R. JAENSCH. 'Ueber die Vorstellungswelt der Jugendlichen und den Aufbau des intellektuellen Lebens:' P. Krellenberg. 'v. Ueber die Herausdifferenzierung der Wahrnehmungs- und Vorstellungswelt aus der originären eidetischen Einheit.' [If the image of sense-memory (*Anschauungsbild*) is the matrix out of which all perceptive and ideational experience has developed, it should be possible to discover examples of the undifferentiated *Einheitstypus*. Such individuals may, in fact, be found; they show no difference, under various experimental conditions, of after-image, image of sense-memory, memory-image; for them the eidetic state is the natural, ordinary psychophysical condition. They are very often of tetanoid constitution, and by medical treatment may be brought to imaginal dissociation. The memory-images most resistant to change from the original type are those of interesting (important, meaningful) objects and of form (as means of orientation).] J. PLASSMANN. 'Die Milchstrasse als Gegenstand der Sinneswahrnehmung.' [Aside from its astronomical and psychophysical (star-magnitudes) interest, the Milky Way offers problems to psychology both by its actual appearance and by reason of the divergence of its pictorial representations.] G. RÉVÉSZ. 'Tierpsychologische Untersuchungen: Versuche an Hühnern.' [Notes on color-contrast; on apprehension of quantities and tendencies to choice (extremes of a series are taken); on precision of pecking movements; and on formal effect of practice.] Literaturbericht.

Arch. f. d. ges. Psychologie. Bd. xli., Heft 3 u. 4. M. MOERS. 'Untersuchung über das unmittelbare Behalten bei verschiedenen Darbietungsarten und über das dabei auftretende totale und diskrete Verhalten der Aufmerksamkeit.' [Experiments with letters and meaningless syllables. (1) With visual presentation, an exposition of the stimuli at rest and spatially juxtaposed is preferable to their exposition in movement and at the same place; the former mode simplifies eye-movement (secures clearer visual images) and facilitates localization.

Auditory presentation is on the average almost as favorable as the better mode of visual. In particular, it is more advantageous for the auditory type than for the visual-auditory type; and it gives better results than visual presentation with the purely visual type, since it makes less demands upon energy. (2) The experiments confirm Meumann's distinction of total and discrete attention; the two forms admit of precise differentiation. In discrete attention, the characteristic features of immediate (as opposed to permanent) retention are strongly repressed.] R. RUDLOWSKI. 'Kasuistischer Beitrag zur Psychologie der Aussage.' [Actual incidents are more instructive than picture-experiments. The emotional factor increases the percentage of wrong statements made under oath, and is more disturbing to women than to men.] T. LEHMANN. 'Zur Psychologie des Vergleichs kurzer Zeiten.' [Experiments with short empty intervals (made by means of an ingeniously simple apparatus) confirm Katz' finding of unimembral judgments; the interval of comparison may be the sole basis of judgment, without increase of the *DL*, without any sort of conscious representation of the standard interval, and without recourse to secondary aids to comparison. This result is a matter of sensory *Einstellung*, which may be surprisingly persistent.] E. CZUBER. 'Zur Theorie der linearen Korrelation.' W. WIRTH. 'Bemerkungen zu der vorangehenden Abhandlung von Herrn Prof. E. Czuber über die Theorie der linearen Korrelation.' W. WIRTH. 'Nachwort.' [Discussion of certain points in Wirth's "Spezielle psychologische Massmethoden" (Abderhalden's *Handbuch der biologischen Arbeitsmethoden*, 1920).] M. TITTEL. 'Ueber Angleichung und Kontrast im Tongebiet.' [Determination of the *DL* of successive fork-tones, when the standard (*N*) is preceded by an inducing (*I*) stimulus. Assimilation occurs when the interval *I-N* is less, contrast when it is greater than an octave. (The one exception to this rule is the appearance of assimilation in place of contrast with musical *Os* and pure consonant intervals.) The assimilative effect is greater than that of contrast; it is greatest with neighboring *N* and *V* (second, minor third), least with the intervals of fourth and fifth. The effect of contrast in its sphere (large, mistuned intervals) is approximately the same for all intervals. The absolute magnitude of the induction-effect increases with rise of pitch-number. Induction is centrally conditioned.] A. FISCHER. 'Alexius Meinong.' A. BERLINER. 'Bestimmung der Zuverlässigkeit bei der Methode der relativen Stellung mit besonderer Berücksichtigung der Werbeforschung.' [Formulas and illustrations.] A. BERLINER. 'Zusammenhang zwischen aesthetischem Wert und Wiedererkennen.' [Experiments on the rank-order of postcard pictures show that the aesthetically preferred members of a group are also the more easily recognized.]

Arch. f. d. ges. Psychologie. Bd. xlii., Heft 1. u. 2. E. BERNER. 'Allgemeine Untersuchung der zwischensubjektischen Beziehungen bei den neueren deutschen Skeptikern.' [The problem of intersubjective relations has received four typical solutions: the negative or solipsistic (Schubert-Soldern, Keibel, Ziehen); the positive by way of a real external world (Goering, Schubert-Soldern, Schmidt); the positive by way of objective assumption of an external world (Bergmann, Weishaupt, Cornelius); and the sceptical (Heim, Spir, Im. Fichte, Stirner, Nietzsche).] K. KORNILOFF. 'Dynamometrische Methode zur Untersuchung der Reaktionen, [Bulb-key, manometer and kymograph are introduced into the chronoscope circuit. In the muscular reaction, short time goes with increased energy and increase of the numbers (Isserlin's constants) expressing the form of movement; in the sensory reaction these relations are reversed. In general, the more complicated the activity of thought, the less intensive is the outward manifestation of the voluntary action.] O. KLEMM. 'Ueber die Korrelation verschiedenartiger Auffassungsleistungen bei Eignungsprüfungen.' [Tables, with brief discussion, of correlations between range

of attention, immediate retention, counting of irregular point-groups, and reading-off of colors and color-names.] J. LINDWORSKY. 'Beiträge zur Lehre von den Vorstellungen.' [(1) The spontaneous arousal of palpable ideas in the course of a thought-experience is due to a pause in (or retardation of) the thought. This fact may mean that thought is in general dependent upon such ideas *in statu nascendi*, but moves too quickly for their realisation. (2) The usual, perhaps the normal, mode of development of ideas is from general to particular.] W. MÖHRKE. 'Beitrag zur Untersuchung der Schmerzempfindung.' [(1) Experimentally produced pain has no effect on the performance of even difficult mental tasks. (2) Adaptation to pain appears under all forms of electrical stimulation: oscillating and constant direct current and faradisation. The pain-quality under the oscillating current is dull and boring; under the constant current, cutting. The oscillating current affects the pressure organs and induces anaesthesia; the constant current hardly affects the pressure organs but arouses warmth. Adaptation is a specific effect of electrical stimulation, and may be explained on Braun's theory.] F. NICOLAI. 'Experimentelle Untersuchungen über das Haften von Gesichtseindrücken und dessen zeitlichen Verlauf.' [Experiments on children and unintellectual adults show that, after a single exposure of a group of familiar visual objects, there is at first much forgetfulness but later (up to periods of four weeks) a marked return to memory. Repeated reproductions serve involuntarily to fix the ideas in memory; an immediate reproduction is of especial effect. As the number of objects increases, the span of memory also increases, tending to a maximum. If a large number of objects are presented in successive groups there is confusion, not as regards the number retained but as regards their localisation.] E. BECHER. 'Benno Erdmann.' Gesellschaft für experimentelle Psychologie: Ausschuss für angewandte Psychologie. W. WIRTH, W. ENGELMANN. 'Alfred Lehmann.'

Arch. f. d. ges. Psychologie. Bd. xlii., Heft 3 u. 4. M. KIEFER. 'Experimentelle Untersuchung über die quantitativen und qualitativen Beziehungen der monauralen und binauralen Schalleindrücke, sowie deren Verwertung zur Deutung des Weber-Fechnerschen Gesetzes.' [Reports experiments with the gravity phonometer, monaural and binaural, undertaken to determine the locus of the logarithm in Fechner's formula for Weber's Law. Monaural and binaural impressions differ in quality and in localisation; intensity and quality depend on attention, which is always locally directed; localisation of the source of sound may be disturbing, as correcting judgments of intensity. The relative *DL* is smaller binaurally, with high intensity of stimulus; with low intensity, the monaural and binaural *DL* are about the same. The binaural *RL* is always lower than the monaural. The ratio of R-intensities, binaural and monaural, which gives subjectively equal sounds, is (weak) 1:2.46, (strong), 1:5.49. As regards Weber's Law, the results are ambiguous.] E. MALLY. 'Ueber die Bedeutung des Bravais-Pearsonschen Korrelationskoeffizienten.' [Derives the measure of correlation from the concept of the "elementary case of connected variations."—W. Wirth adds a critical note.] N. VON MAYENDORF. 'Der Sehhügelstiel des inneren Kniehöckers und seine physiologische Bedeutung.' [The fibres mediate reflex connection between excitations of the cochlearis and the cortical area for bodily sensitivity (start on hearing of sudden noise, shudder at squeak of blackboard chalk, etc.).] A. BERLINER. 'Reduktion der mittleren Verschiebung bei der Methode der relativen Stellung.' [In the arrangement by rank-order the various measures of distribution are reduced by division by n (or by a value which with infinitely large n approximates infinitely closely to n) to an expression which is independent of n, the number of elements.—W. Wirth adds a critical note.] R. H. GOLDSCHMIDT. 'Rückblick auf Nachbildtheorien bis zur Herausbildung der Fechner-Helmholtzschen Auffassung.' [Discusses in particular

the fatigue-theory of Scherffer and Chevreul, the oscillation-theory of Godart, Brewster and Plateau, and the work of Aubert. In general the after-image has been regarded and studied as of peripheral origin; there are, however, many features of it—mode of appearance (Katz), general structure (Jaensch), form as compared with original, sharpness of outline, details, etc.—which point to central conditions.] R. H. PEDERSEN. 'Alfred Lehmann.' [Appreciation, with portrait.] K. GNEISSE. 'Die Entstehung der Gestaltvorstellungen, unter besonderer Berücksichtigung neurerer Untersuchungen von kriegsbeschädigten Seelenblinden.' [Utilises the work of Gelb and Goldstein, Fuchs and Poppelreuter for a critical examination of three theories of form: those of Wertheimer, of Linke, and of Meinong and his pupils. Decides in favor of the Austrian school.] S. FISCHER. 'Ueber das Entstehen und Verstehen von Namen, mit einem Beitrage zur Lehre von den transkortikalen Aphasien, i.' [Reports experiments with meaningless linear figures and photographs of unknown persons, to which meaningless names of one, two and three syllables were (for the most part auditorily) attached. After discussing the experiences of impression (*Einprägung*), the author seeks to determine the conditions under which the sound assumes a nominal function. It is important that the object be logically determinate (manifest a 'structure') and be apprehended as important (useful, significant), and that the sound be apprehended as a form or complex.]

Psychological Review. Vol. xxviii., no. 2. S. I. FRANZ. 'Cerebral-mental Relations.' [While mental alterations accompany cerebral lesions, there may be subsequent return to a normal (or nearly normal) mental state without corresponding recovery of normal brain-condition; we do not observe a definite dependence of a special mental state on the integrity of certain special cerebral parts. A better physiological psychology is sorely needed.] L. L. BERNARD. 'The Misuse of Instinct in the Social Sciences.' [An instinct is a specific inherited action-pattern. Thus it is wrong to apply the term to habit-complexes, to think of instinct as involving a conscious element, to make purposiveness a characteristic of it, to seek to define it in terms of the function of the act. The real task of the educational and social psychologist is to discover the mechanisms whereby child and citizen build up their habits, directly and indirectly, on the basis of instincts, and whereby one habit or set of habits is transformed into another.] J. R. KANTOR. 'An Attempt toward a Naturalistic Description of Emotions, ii.' [Emotions are not of general and necessary utility to the organism; are not related to instincts; as no-response actions, cannot readily be classified; are seldom if ever found in animals and young children; do not admit the dichotomy of emotional act and expression. Their conditions are constitutional (equipment of response-patterns, speed of reaction, etc.) and stimulational (familiarity with stimulus, setting of stimulus, etc.).] E. L. THORNDIKE. 'On the Organization of Intellect.' [Results of 15 tests of intelligence given to about 800 soldiers, of 7 tests of intellect and skill given to over 900, and of 9 tests of intellect given to 653 individuals, are adverse to Spearman's theory in any strict form. Further work of detail is suggested.]

NOTES

Note on Plethysmographic Technique

Inasmuch as the regular rubber sleeves for the Lehmann plethysmograph are not yet procurable, and as the American manufacturers are no longer making bladder spinal ice-bags, which proved to be an admirable substitute, one has had to use rubber gloves for this sort of experiment. It is worth noting that elbow-length obstetrical rubber gloves are now available for the first time since the war. Rubber gloves have proved to be relatively unsatisfactory for this work, owing to the difficulty with which the hand is inserted and withdrawn. Two expedients have been used: either the hand and arm have been covered with vaseline, or the hand has been inserted in the glove which has subsequently been attached to the metal sleeve. These inconveniences may be obviated by the following simple trick. Attach the rubber glove to the metal sleeve in the usual way. Then turn off the stopcock through which the water is to be inserted and, by applying the mouth to the top of the glass tube, draw out all the air between the rubber glove and the metal sleeve. This proceeding distends the rubber glove, so that the hand may be readily inserted. It has also been found advisable to draw out the air at the end of experimentation, after the water has been removed, to enable the subject to withdraw the hand easily from the apparatus.

S. W. Fernberger

University of Pennsylvania

"The Physical Growth of Children"

I am indebted to Professor L. B. Hoisington for his careful analytical review, in the April number of this Journal, of my recent Study, *The Physical Growth of Children from Birth to Maturity.*

The printing of the Study proved difficult for the local printer with limited facilities. I take this opportunity to correct some of the inconsistencies emphasized in the review by Professor Hoisington, since they are also of psychological significance to those interested in typesetting and proof-reading. "Left" was printed for "right" (p. 21); "girls" for "boys" (p. 147); and "above" for "below" (p. 192).

Bird T. Baldwin

University of Iowa

A Note on "Affirmation and Negation"

A word of critical comment on the interesting experiments of Dr. C. H. Griffits reported in the January, 1922 number of this Journal may not be amiss. The purpose of the experiments was to disprove the common opinion, as represented by Professor Breese and others, that the difference between judgments of affirmation and of negation is a logical rather than a psychological one,—that all judgments are, from a psychological point of view, affirmations.

The results of the experiments undoubtedly show that it takes more time to form a negative judgment than it does to establish an affirmative one; but is this not after all what would be supposed from ordinary observation? To infer further from this, however, that consequently there is a psychological *opposition* between a logical affirmation and a logical nega-

tion is hardly warranted. To judge that "the table is not round", "this color is not red", "these letters are not present", etc., no doubt ordinarily requires a longer time than that needed to make the respective opposite judgments; but, after all, the psychological attitude taken toward a roundness or a redness disbelieved in is the same in kind as that taken toward a not-roundness or a not-redness believed in, however much the time necessary to arrive at these attitudes may differ in duration in the two cases. In other words, the only *opposition* between affirmation and negation seems to be a *logical* opposition: the only *psychological* difference is a difference in *duration* of process, not an opposition at all. I do not see, therefore, that Dr. Griffits has proved his point as a result of his experiments.

J. S. Moore

Western Reserve University

The "Elements of Folk Psychology"

The publishers of the English Translation of Wundt's *Elemente der Völkerpsychologie* tell me that the words "Revised edition April 1921" which appear in the new issue are due to a mistake made by their printing department and will be removed from all copies now in stock. My remarks in this Journal, xxxiii., 1922, 150 ff. must therefore be taken as belated comments on the original edition.

E. B. T.

Urban's Tables Yet Again!

Dr. G. J. Rich points out that the value 2.2365 in the last line of p. 303 *sup.* should be 2.2363.

Augustus Désiré Waller

Professor A. D. Waller, since 1902 director of the physiological laboratory of the University of London, and for many years an associate editor of this Journal, died on March 11, at the age of sixty-five. Waller's physiological researches covered a wide range (see *Nature*, cix., April 1, 1922, 418 f.). He is best known to psychologists by his studies of the sense of effort (*Brain*, 1891) and of the psychogalvanic reflex (*Proc. Roy. Soc.*, 90 B, 1917-19, etc.). In 1891 he published *An Introduction to Human Physiology*, which showed a keen interest in psychophysical problems, and in 1912 he ventured a *Psychology of Logic*.

APPOINTMENTS

At Harvard University, Dr. Herbert S. Langfeld and Dr. Edwin G. Boring have been appointed associate professors of psychology and Dr. Carroll C. Pratt instructor in psychology. Dr. Langfeld is promoted from an assistant professorship at Harvard. Dr. Boring has been professor of experimental psychology since 1919, and Dr. Pratt instructor in experimental psychology since 1921, at Clark University. The psychological staff at Harvard will consist of Professors McDougall and Dearborn, Associate Professors Langfeld and Boring, Dr. Troland, and Dr. Pratt.

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Hugo Münsterberg

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By Margaret Münsterberg

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